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A Consideration on Differences of Catch Compositions between Daytime and Nighttime Bottom Trawl Samplings in the East China Sea (in Japanese)
Masanobu MATSUOKA, Muneharu TOKIMURA, Hitoshi FUJJTA and Tadahiro KITAJIMA
Bull. Seikai Natl. Fish. Res. Inst., (70), 1-9 (1992)

Differences of catches and catch compositions between daytime and nighttime were examined based on the bottom trawl samplings in the East China Sea. Three pairs of daytime and nighttime tows were carried out. The total weight and number of individuals of the daytime catches were higher than those of the nighttime ones. The weights and numbers of catches of *Loligo edulis*, *Psenopsis anomala*, *Pampus echinogaster* and *Trichiurus lepturus* were higher in the daytime than in the nighttime, while those of *Branchiostegus japonicus*, *Hoplobrotula armata*, *Metanephrops thomsoni*, etc. were higher in the nighttime than in the daytime. No significant difference was observed between daytime and nighttime catches in *Ibacus ciliatus ciliatus*, *Doederleinia berycoides*, etc.. It was suggested that differences of trawl catches between daytime and nighttime should be carefully taken into consideration to examine the stock conditions of groundfishes for stock management purposes.
Key words : bottom trawls, daytime, nighttime, diurnal variations, catch compositions, East China Sea

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Reproduction of the Freshwater Stingray, *Potamotrygon magdalenae* Taken from the Magdalena River System in Colombia, South America
Kazuyuki TESHIMA and Koji TAKESHITA
Bull. Seikai Natl. Fish. Res. Inst., (70), 11-27 (1992)

Reproductive biology of the freshwater stingray. *Potamotrygon magdalenae* was examined while conducting research on freshwater elasmobranchs in Colombia, South America from August 12 through August 19, 1980. A total of 117 *P. magdalenae* specimens (female; 44, male; 73) were taken by gillnet in lakes near the Magdalena River system in the northern Colombia. After mesuring and observing external characteristics of the stingrays, reproductive organs removed were preserved in formalin and brought to Japan for histological observations. Unlike many other female elasmobranchs, oogenesis in *P, magdalenae* was characterized by unusual folds that were formed on the follicular epithelium. The follicular epithelial folds, that extended inward into the oocyte, filled the oocyte before it reached the maturity. After ovulation, the follicular epithelial folds were freed from the mature oocyte and remained in the postovulatory follicle. Ovulation appears to occur when the oocyte reaches the diameter of about 25 mm. *P. magdalenae* has a non-placental viviparous mode of reproduction and a single embryo develops in each uterus. Size at birth for the embryos is estimated to be about 100 mm in disk width. *P. magdalenae* is estimated to reach the maturity between 170 and 210 mm disk width in females and between 170 and 190 mm disk width in males. Based on the development of ovaries and testes, the size of embryos found in uteri, and the estimated size at birth, the reproductive activity including ovulation, mating, fertilization, and parturition might take place over an extended period of time, therfore suggesting that *P. magdalenae* might not have a definitive reproductive season.
Key words : freshwater stingray, Magdalena River, *Potamotrygon magdalenae*, Reproduction, Oogenesis, follicular epithelail folds

Mortality of Reared Flounder (*Paralichthys olivaceus*) Juveniles Released in Shijiki Bay (in Japanese)

Hiroyuki SUDO, Tsuneo GOTO, Reiko IKEMOTO, Minoru TOMIYAMA and Masanori AZETA

Bull. Seikai Natl. Fish. Res. Inst., (70), 29–37 (1992)

Experimental releases of 37,000 (33.7 mm TL) and 24,600 (81.2 mm TL) reared flounder juveniles were carried out in Shijiki Bay in 1985 and 1986, respectively, to elucidate the process and mechanism of their mortality. Total numbers of recaptured fish were 577 and 450 in 1985 and 1986, respectively, and most of them were caught within 10 days after release. Decrease rates of released fish were therefore high in both years (17.6%$\cdot$day^{-1} in 1985 and 45.1%$\cdot$day^{-1} in 1986). However, the process of their decrease and adaptation was different. In 1985: (1) the decrease rate of small fish (TL$<$35 mm) was higher than that of large ones; (2) albinic fish decreased more rapidly than normal ones; and (3) feeding incidence was low. In 1986: (1) there was no difference in decrease rate between small (TL$<$75 mm) and large fish; (2) decrease patterns were similar between albinic and normal fish; and (3) feeding incidence was high. These results suggest that the most significant cause of decrease of released fish was predation in 1985 and dispersal in 1986, because it is easy for predators to catch and handle small and starving fish and to detect albinic fish.

Key words: flounder, *Paralichthys olivaceus*, released fish, mortality, starvation, predation, albinism

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Preliminary Observation of Swimming and Feeding Behaviours for the Natural Population of Early Juvenile Red Sea Bream *Pagrus major* in Relation to Copepod Swarm

Yasuhiro MORIOKA and Junko NAKASHIMA

Bull. Seikai Natl. Fish. Res. Inst., (70), 39–46 (1992)

Scuba diving observation was made at 4 sites with the depth of sea bottom of 7 to 14 m in the coastal area of Nagasaki Peninsula, western Kyushu, during May and June, 1990. The early juveniles of *Pagrus* were swimming keeping a distance of 3 to 5 cm and sometimes about 10 cm above the sea bottom without attaching to the bottom even for a moment. They swam vigorously without intermission at sites where the swarm did not develop and usually in straight path. The distance of a single dart ranged from 30 to 50 cm. On the other hand, they tended to stay still at a certain position in the sites where copepod swarm developed. A *Pagrus* juvenile was moving its lips continuously at the edge of a copepod swarm in a hollow of a diameter about 20 cm. The results of stomach contents survey for 5 individuals (13 to 17 mm in fork length) caught suggested a flexible food habit for early juvenile *Pagrus*.

Key words: juveniles, *Pagrus major*, scuba diving, feeding behavior, swimming, stomach contents, copepoda, aggregation

Further Investigation of Zooplankton Biomass Share in the Collections with Plankton Net in the Waters to the West of Kyushu

Junko NAKASHIMA, Yasuhiro MORIOKA and Katsunori KIMOTO

Bull. Seikai Natl. Fish. Res. Inst., (70), 47-54 (1992)

This sequel study was carried out to estimate the amount of very zooplankton in a plankton net haul. Vertical hauls with the triplet plankton nets (45 cm in mouth diameter, filtering cloths of 335, 200 and 100 μm mesh aperture each) were made once at a site and three times at another sites in the Goto-nada waters off western Kyushu, in May 1987. Zooplankters were separated from phytoplankton and carcass of phytoplankton and zooplankton by hand under dissecting microscope.

The component ratios of zooplankton biomass were rather constant among mesh sizes and sampling stations ranging from 83 to 89% of the whole collection. The relative abundance of phytoplankton biomass converted from chlorophyll *a* increased and that of the carcass decreased when the mesh size decreased, occupying 2 to 16% and 2 to 12%. respectively.

Key words: biomass zooplankton, phytoplankton, carcasses, biological collections, plankton collecting devices

On the Mixing Process of the Oyashio Water off South-East coast of Southern Part of Kuril Islands (in Japanese)

Kenji MORINAGA and Takashige SUGIMOTO

Bull. Seikai Natl. Fish. Res. Inst., (70), 55-64 (1992)

Focusing on the mixing process between Okhotsk Sea Water (OSW) and East Kamchatka Current Water (EKCW), we carried out experiments (ALGOS buoy and oceanographical survey) around the Kuril Islands from September to November 1992.

It was revealed that 1) the Oyashio current path lays along the south of the southern Kuril Islands, 2) off Shikotan island, it took a great offshore bend due to the Kuroshio Warm Core Ring (KWCR), 3) mixing rate of OSW and EKCW increased gradually, and its time derivative had a constant value, and 4) in the periphery of the subarctic boundary, appeared a rapid stream that reached up to 60 cm/sec.

Consequently, characteristics of the Oyashio Water might have varied according to the change of its path influenced by the KWCR. Furthermore high velocity periphery current of the subarctic boundary reveals the existence of rapid eastward countercurrent of anticyclonic subarctic circulation in the North Pacific.

Key words: Oyashio, Kuroshio Warm Core Ring, mixing process, drifting buoy, oceanographical condition, subarctic boundary

東シナ海におけるトロール漁獲物組成の昼夜差に関する一考察

松岡正信*・時村宗春*・藤田　矗**・北島忠弘***

A Consideration on Differences of Catch Compositions between Daytime and Nighttime Bottom Trawl Samplings in the East China Sea

Masanobu MATSUOKA*, Muneharu TOKIMURA*, Hitoshi FUJITA**
and Tadahiro KITAJIMA***

ABSTRACT

Differences of catches and catch compositions between daytime and nighttime were examined based on the bottom trawl samplings in the East China Sea.

Three pairs of daytime and nighttime tows were carried out, using trawl net with 66 mm mesh cod end and a double cover net consisting of cover net I (inner, 18 mm mesh) and II (outer, 10.3 mm mesh).

In the case of catches of all the species included, the total weight and number of individuals of the daytime catches in cod end were higher than those of the nighttime ones, while the daytime catches in cover net II were significantly lower than the nighttime ones.

As for catches by species in cod end, the weights and numbers of catches of *Loligo edulis*, *Psenopsis anomala*, *Pampus echinogaster* and *Trichiurus lepturus* were higher in the daytime than in the nighttime. On the other hand, those of *Branchiostegus japonicus*, *Hoplobrotula armata*, *Metanephrops thomsoni*, etc. were higher in the nighttime than in the daytime. No significant difference was observed between daytime and nighttime catches in the case of *Ibacus ciliatus ciliatus*, *Doederleinia berycoides*, etc..

It was suggested that differences of trawl catches between daytime and nighttime should be carefully taken into consideration to examine the stock conditions

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of groundfishes on the basis of trawl survey and to analyse the commercial catch data from this area for stock management purposes.

トロール曳網による漁獲物の量や種組成には昼夜により様々な差があるといわれている[1-3]．東シナ海・黄海の底魚類についてもこれに関するいくつかの報告があるが，多くは漁船操業記録からの推定であり[4-8]，調査船により実際にトロール曳網を行い，その差異について検討した例は少ない[9]．

トロール漁獲物における種組成や種別漁獲量の昼夜差について詳細に把握しておくことは，底魚資源生態研究の基礎資料となるだけでなく，資源評価の精度向上にもつながるものと考えられる．本研究は，このような視点から，東シナ海において同一地点で夜間と昼間にトロール曳網を行い，それぞれの漁獲物組成等について予備的に比較検討したものである．

本研究を行うにあたり，調査にご協力いただいた熊本県立水産高校練習船「熊本丸」の吉田明治船長はじめ乗組員各位に心から御礼申し上げる．また，甲殻類の査定に関して多くの助言をいただいた西海区水産研究所下関支所　田川　勝底魚資源研究室長に感謝の意を表する．

方　　　法

調査は熊本県立水産高校練習船「熊本丸」(380トン)を用船し，1986年12月14日から15日にかけて行った．14日22時より北緯31°30′，東経127°15′付近から南東方向に3回の夜間曳網（夜網）を行った．翌15日には最初の地点に戻り，10時より夜網に近接しかつ平行するように3回の曳網を行った（昼網）．トロール網には漁網監視装置（Scanmer Catch Control System）を取り付け，曳網中の袖網間隔及び網高さを記録した(Fig. 1, Table 1)．

用いたトロール網はコッドエンド目合66mm（外寸）のもので，小型生物の採集を目的としてコッドエンドの外側に目合18mmのカバーネットⅠ，さらにその外側に目合10.3mmのカバーネットⅡを取り付けた．コッドエンドの採集物については，魚類，甲殻類及び頭足類の種別総個体数及び種別総重量を計測し，主要種については体長測定を行った．カバーネットⅠ及びⅡによる採集物については，総重量を測定後，一部を標本としてホルマリン固定して持ち帰った．これらについてコッドエンドの採集物と同様の測定を行い，種別総個体数及び種別総重量を比例計算によって求めた．

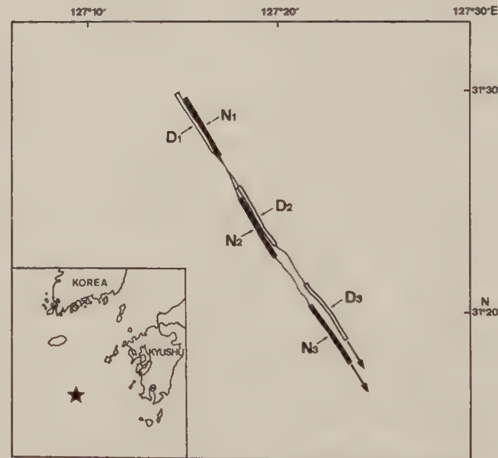


Fig. 1. 昼夜別トロール試験曳網図
Track lines for daytime(D_1～D_3) and nighttime (N_1～N_3) trawl sampling operations.
★, trawling site.

Table 1. 昼夜別トロール試験の曳網状況
Towing contition of trawl sampling operations in daytime(D_1～D_3) and nighttime(N_1～N_3).

Operation	N_1	N_2	N_3	D_1	D_2	D_3
Date	Dec. 14	Dec. 14-15	Dec. 15	Dec. 15	Dec. 15	Dec. 15
Setting time of net	22：07	23：39	01：12	10：05	11：36	13：08
Duration of tow(min.)	60	60	60	60	60	60
Distance of tow(n.m.)	3.1	3.1	3.0	3.1	3.1	3.1
Depth(m)	108	107	108	108	107	107
Height of net mouth(m)	4.2	4.3	4.5	4.5	4.6	4.8
Distance between wingtips(m)	22.0	22.2	22.4	21.7	21.9	21.6
Area covered per tow($n.m.^2$)	0.0368	0.0372	0.0362	0.0366	0.0366	0.0361

結　　果

トロール曳網状況の概要を Table 1 に示した．曳網中の袖網間隔は21.6～22.4m，網高さは4.2～4.8mであり，曳網面積は0.0361～0.0372n.m.^{2} と各曳網間でほとんど差は認められなかった．そこで，面積換算を行わず，各曳網の採集結果で以下の比較を行った．

昼夜各3回の曳網によりコッドエンドで79種の魚類，甲殻類及び頭足類が採集された．第1及び第3曳網地点では昼夜とも魚類が多く採集されたが，第2曳網地点ではヒラツメガニ *Ovalipes punctatus* が多量に採集されたために甲殻類の比率が高くなった．各曳網地点での採集重量の昼／夜比は，0.95（第1曳網），1.22（第2），1.98（第3），合計では1.36であった．採集個体数，重量及び種数は，魚類では夜間に比べ昼間に多く，一方，甲殻類では夜間に多かった．頭足類

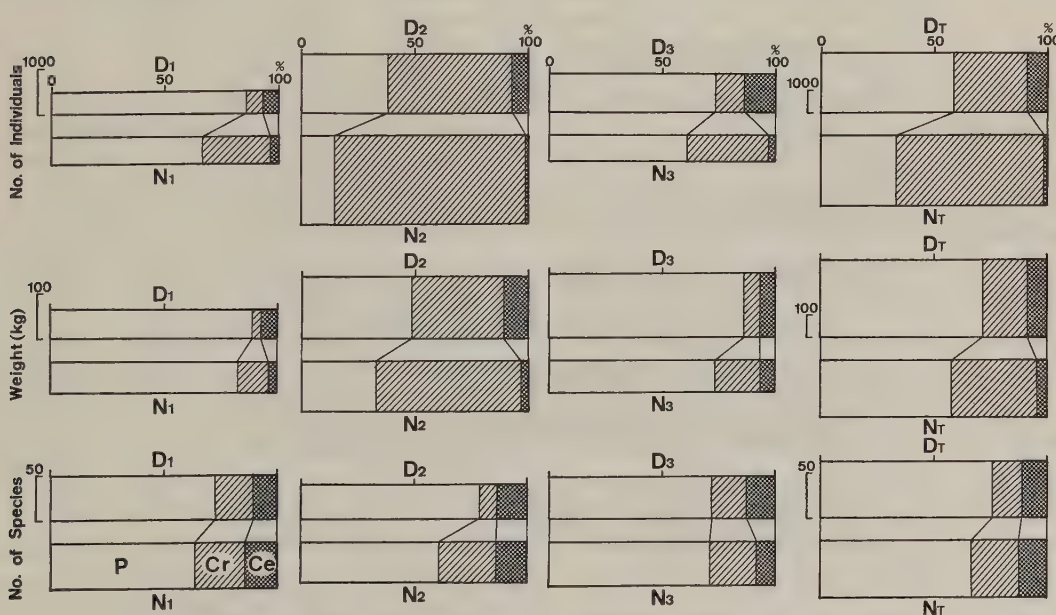


Fig. 2. 昼夜別トロール試験によるコッドエンドの漁獲物組成
Catch compositions by daytime (D_1～D_3) and nighttime (N_1～N_3) trawl samplings.
Ce, Cephalopoda; Cr, Crustacea; P, Pisces; T, total.

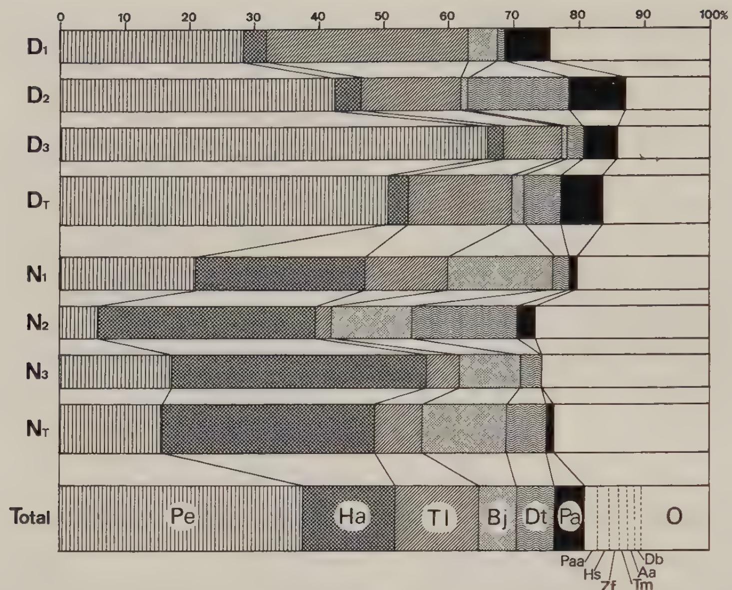


Fig. 3. 昼夜別トロール試験によって採集されたコッドエンドの魚類の種組成（重量百分率）
Species compositions of Pisces in weight caught by daytime ($D_1\sim D_3$) and nighttime ($N_1\sim N_3$) trawl samplings. Aa, shiroguchi *Argyrosomus argentatus*; Bj, akaamadai *Branchiostegus japonicus*; Db, akamutsu *Doederleinia berycoides*; Dt, kidai *Dentex tumifrons*; Ha, yoroiitachiuo *Hoplobrotula armata*; Hs, akagutsu *Halieutaea stellata*; O, others; Pa, ibodai *Psenopsis anomala*; Paa, managatsuo *Pampus argenteus*; Pe, kouraimanagatsuo *Pampus echinogaster*; Tl, tachiuo *Trichiurus lepturus*; Tm, umazurahagi *Thamnaconus modestus*; Zf, matoudai *Zeus faber*.

の種数には昼夜間で大きな差はなかったが，個体数と重量は昼間に多かった（Fig. 2）.

魚類，甲殻類，頭足類それぞれについてコッドエンドの種ごとの重量組成を Fig. 3，4 及び5に示した．魚類ではコウライマナガツオ *Pampus echinogaster*，ヨロイイタチウオ *Hoplobrotula armata*，タチウオ *Trichiurus lepturus*，アカアマダイ *Branchiostegus japonicus*，キダイ *Dentex tumifrons*，イボダイ *Psenopsis anomala* が比較的多く，その他にマナガツオ *Pampus argenteus*，アカグツ *Halieutaea stellata*，マトウダイ *Zeus faber*，ウマヅラハギ *Thamnaconus modestus*，シログチ *Argyrosomus argentatus*，アカムツ *Doederleinia berycoides* 等も採集された（Fig. 3）．甲殻類ではヒラツメガニ，ウチワエビ *Ibacus ciliatus ciliatus*，ミカドシャコ *Kempina mikado*，ミナミアカザエビ *Metanephrops thomsoni*，コシマガニ *Leptomithrax edwardsii*，ハコエビ *Linuparus trigonus* 等が採集された（Fig. 4）．頭足類の採集量は比較的少なかったが，ケンサキイカ *Loligo edulis* が最も多く，他にマダコ *Octopus vulgaris*，コウイカ *Sepia* (*Platysepia*) *esculenta*，スルメイカ *Todarodes pacificus* 等が採集された（Fig. 5）．昼網と夜網の種組成（重量百分率）は，魚類と頭足類では明らかな差が認められたが（Fig. 3，5），甲殻類では顕著な差はみられなかった（Fig. 4）.

主要種について昼網と夜網のコッドエンドの採集個体数を比べると（Fig. 6），ケンサキイカ，イボダイ，コウライマナガツオ，タチウオは専ら昼間に採集され，キダイも昼間に比較的多く採集された．これらの種では，昼夜別採集個体数の χ^2 検定により1％レベルで有意差が認められた．マトウダイ，ウマヅラハギ，ウチワエビ，アカムツでは昼夜間で有意差は認められなかった．一方，アカアマダイ，ヨロイイタチウオ，ミナミアカザエビ，ハコエビ，シオイタチウオ *Neobythites sivicola* は専ら夜間に採集され，ハコエビでは5％，それ以外では1％レベルで有意差が認められた．その他，昼夜で特に有意差がなかった種としてはカイ

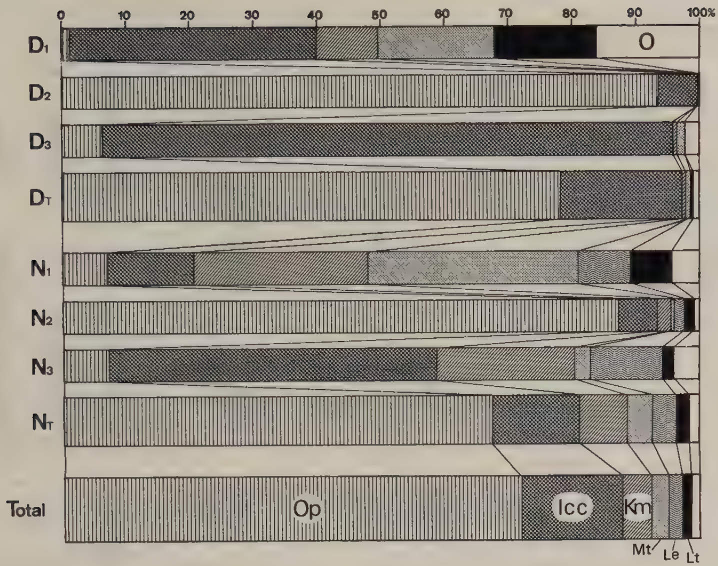


Fig. 4. 昼夜別トロール試験によって採集されたコッドエンドの甲殻類の種組成（重量百分率）
Species compositions of Crustacea in weight caught by daytime ($D_1 \sim D_3$) and nighttime ($N_1 \sim N_3$) trawl samplings. Icc, uchiwaebi *Ibacus ciliatus ciliatus*; Km, mikadoshako *Kempina mikado*; Le, koshimagani *Leptomithrax edwardsii*; Lt, hakoebi *Linuparus trigonus*; Mt, minamiakazaebi *Metanephrops thomsoni*; O, others; Op, hiratsumegani *Ovalipes punctatus*.

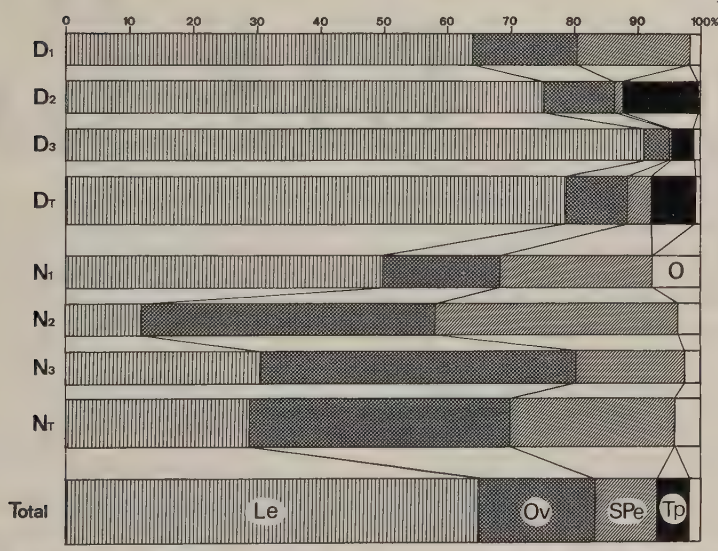


Fig. 5. 昼夜別トロール試験によって採集されたコッドエンドの頭足類の種組成（重量百分率）
Species compositions of Cephalopoda in weight caught by daytime ($D_1 \sim D_3$) and nighttime ($N_1 \sim N_3$) trawl samplings. Le, kensakiika *Loligo edulis*; O, others; Ov, madako *Octopus vulgaris*; SPe, kouika *Sepia* (*Platysepia*) *esculenta*; Tp, surumeika *Todarodes pacificus*.

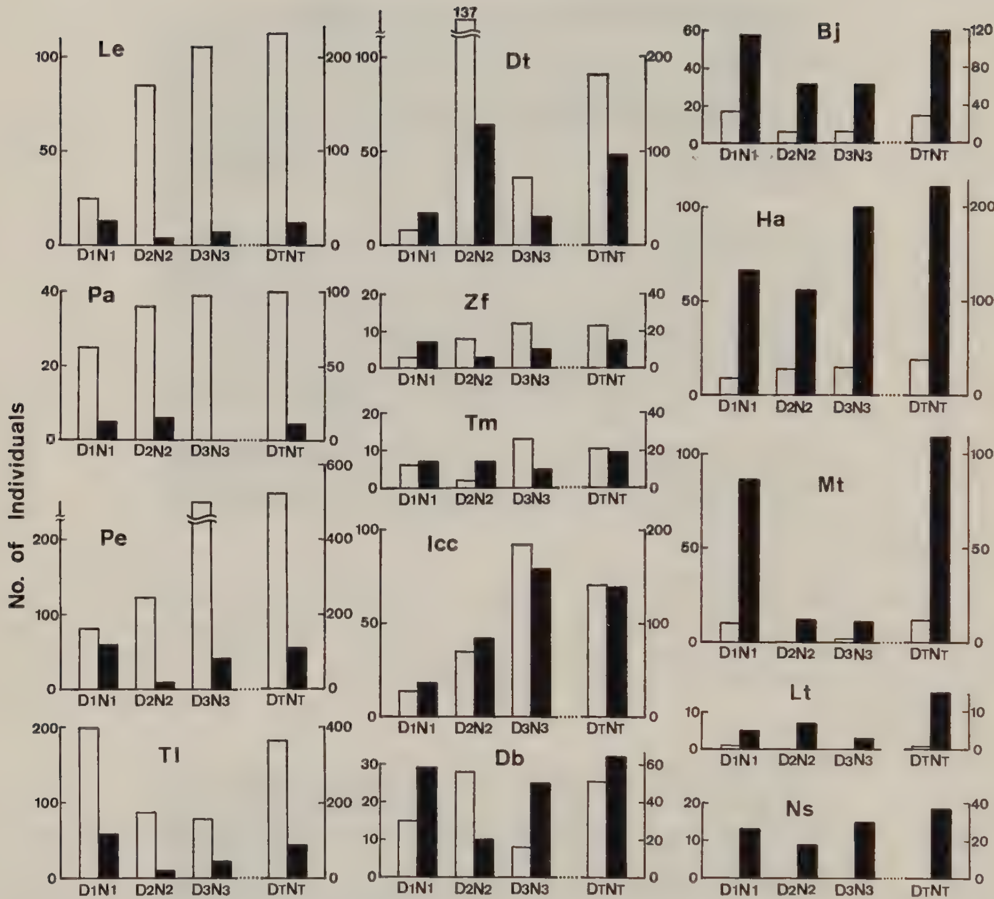


Fig. 6. コッドエンドによる主要種の昼夜別採集個体数比較
Number of individuals by species caught by daytime (D_1～D_3) and nighttime (N_1～N_3) trawl samplings. Bj, akaamadai *Branchiostegus japonicus*; Db, akamutsu *Doederleinia berycoides*; Dt, kidai *Dentex tumifrons*; Ha, yoroiitachiuo *Hoplobrotula armata*; Icc, uchiwaebi *Ibacus ciliatus ciliatus*; Le, kensakiika *Loligo edulis*; Lt, hakoebi *Linuparus trigonus*; Mt, minamiakazaebi *Metanephrops thomsoni*; Ns, shioitachiuo *Neobythites sivicola*; Pa, ibodai *Psenopsis anomala*; Pe, kouraimanagatsuo *Pampus echinogaster*; Tl, tachiuo *Trichiurus lepturus*; Tm, umazurahagi *Thamnaconus modestus*; Zf. matoudai *Zeus faber.*

ワリ *Kaiwarinus equula*，夜間に多く採集された種としてはアカグツ，ヒラツメガニ，シログチ，メイタガレイ *Pleuronichthys cornutus*（ホンメイタ型[10]），ミカドシャコ，コシマガニがあげられる（Fig. 6，Table 2）．Table 2 に検定結果とともに各種別の昼夜間採集重量比，個体数比及び昼夜型を示した．また，図には示していないが，主要種の体長組成には昼夜間で顕著な差は認められなかった．

一方，カバーネットＩでは58種が採集され，ホタルジャコ *Acropoma japonicum*，ワニギス *Champsodon snyderi*，ヒメスミクイウオ *Synagrops philippinensis* 等の魚類が大半を占めた．採集重量は昼網の方が多かったが（3曳網昼／夜比の平均1.26），出現種数では夜網は昼網の約2倍であった（同0.47）．カバーネットⅡでは44種が採集された．一部の種はカバーネットＩと重複しており，上記3種以外に *Lophogaster pacificus*，ミナミシロエビ *Metapenaeopsis philippii*，ウナギ亜目 Anguilloidei 仔魚等が比較的多く認めら

Table 2. 種別の昼夜間採集重量比，個体数比及び昼夜型
Day/night ratio in weight (Dw/Nw) and day/night ratio in number (Dn/Nn) of catch, and catch type of each species.

Species	Dw/Nw	Dn/Nn	χ^2-test in number	Type
Cod end				
Kensakiika *Loligo edulis*	7.22	9.42	++	day
Ibodai *Psenopsis anomala*	9.76	9.09	++	day
Kouraimanagatsuo *Pampus echinogaster*	5.34	4.93	++	day
Tachiuo *Trichiurus lepturus*	3.62	4.09	++	day
Kidai *Dentex tumifrons*	1.54	1.89	++	day
Matoudai *Zeus faber**	1.70	1.53	—	equal
Kaiwari *Kaiwarinus equula**	1.22	1.53	—	equal
Umazurahagi *Thamnaconus modestus**	1.00	1.11	—	equal
Uchiwaebi *Ibacus ciliatus ciliatus*	0.99	1.01	—	equal
Akamutsu *Doederleinia berycoides*	0.77	0.80	—	equal
Akagutsu *Halieutaea stellata**	0.56	0.49	+	night
Hiratsumegani *Ovalipes punctatus*	0.82	0.44	++	night
Shiroguchi *Argyrosomus argentatus**	0.34	0.32	+	night
Meitagarei *Pleuronichthys cornutus**	0.35	0.29	+	night
Akaamadai *Branchiostegus japonicus*	0.24	0.24	++	night
Yoroiitachiuo *Hoplobrotula armata*	0.16	0.17	++	night
Minamiakazaebi *Metanephrops thomsoni*	0.14	0.11	++	night
Hakoebi *Linuparus trigonus**	0.18	0.07	+	night
Mikadoshako *Kempina mikado*	0.04	0.04	++	night
Shioitachiuo *Neobythites sivicola*	0	0	++	night
Koshimagani *Leptomithrax edwardsii*	0	0	++	night
Cover net I and II included				
Kensakiika *Loligo edulis*	823.13	36.60	++	day
Jindouika-azoku *Loligo (Nipponololigo)*	4.69	5.25	++	day
Hotarujako *Acropoma japonicum*	2.77	2.62	++	day
Himesumikuiuo *Synagrops philippinensis*	0.14	0.07	++	night
Komochijako *Amblychaeturichthys sciistius*	0.04	0.06	++	night
Minamishiroebi *Metapenaeopsis philippii*	0.03	0.02	++	night
Unagi-amoku Anguilloidei (L)	0.03	0.02	++	night
Akamutsu *Doederleinia berycoides* (J)*	<0.02	0.02	++	night
Wanigisu *Champsodon snyderi*	0.03	<0.01	++	night
Lophogaster pacificus	<0.01	<0.01	++	night
Benikawamuki *Triacanthodes anomalus* (J)	0	0	++	night
Saiuo-zoku *Bregmaceros*	0	0	++	night
Chouchoueso *Synodus macrops* (J)*	0	0	++	night

*, <100 specimens in total catch; J, juvenile; L, larva; ++, 1% significant; +, 5% significant; —, not significant

れた．採集重量は夜網の方が著しく多く，昼網の16〜41倍に達した（同0.04）．また，夜網における出現種数は昼網の約2倍であった（同0.45）．

カバーネットIとカバーネットIIとを含めた採集物のうち，主要種について昼夜の採集量を比較すると，小型のケンサキイカ，ジンドウイカ亜属 *Loligo* (*Nipponololigo*)，ホタルジャコは専ら昼間に採集された．他方，ヒメスミクイウオ，コモチジャコ *Amblychaeturichthys sciistius*，ミナミシロエビ，ウナギ亜目仔魚，アカムツ稚魚，ワニギス，*Lophogaster pacificus*，ベニカワムキ *Triacanthodes anomalus* 稚魚，サイウオ属 *Bregmaceros*，チョウチョウエソ *Synodus macrops* 稚

魚は専ら夜間に採集された．これらの種では，昼夜別採集個体数の χ^2 検定により1％レベルで有意差が認められた（Table 2）．

考　察

今回の調査結果から，東シナ海産底魚類の多くの種においてトロール曳網による漁獲量には昼夜差のあることが認められた．既往の報告と比較すると，イボダイ及びコウライマナガツオが昼間に多く漁獲されるという点は，最首・小島[5]及び山田[8]と一致する（山田[8]の“マナガツオ”にはコウライマナガツオが含まれていると考えられる）．また，メイタガレイが夜間にやや多く漁獲されるという点は，最首・小島[5]と一致する．一方，今回昼間に多く漁獲されたタチウオは，小型魚は昼間，大型魚は夜間に多い[5]，夜間[7]あるいは昼間[9]に多い等，一部相反する結果も報告されている．同様の例はシログチにもあり，また，キダイ及びアカアマダイでも既往の報告とは若干異なった結果が得られた．このような相違のひとつの原因として，これまでの漁船操業記録を用いた報告では昼夜による曳網時間の長短を考慮していない場合が多いことがあげられる[4,5,7,8]．最首[6]及び山田[8]によると，以西底びき網漁船は一般に昼間は1.5時間前後，夜間は2～3時間曳網しており，単に一曳網当たり漁獲量で比較することはできないと考えられる．さらに，同一種でも海域やサイズによって昼夜の漁獲能率が変化する可能性がある[1]．最首・小島[5]は数種の魚類において昼夜別漁獲量及び罹網率から推定される分布パターンが成長段階によって変化することを報告している．今回の例でも，尾叉長9.5～21.5cmのアカムツでは昼夜による差が認められなかったのに対して，2㎝前後の同稚魚は専ら夜間に採集された．このような点から，今後は季節，海域，成長段階等をも考慮に入れた調査データの蓄積が必要であろう．

昼夜によるこのような漁獲差が生じる主要因として，Parrish et al.[1]は鉛直移動及び漁具に対する視覚的反応の差を指摘している．また，Walsh[2]はyellowtail flounder *Limanda ferruginea* が夜間に多く漁獲される理由として，夜間には摂餌活動や漁具に対する逃避行動が弱まるためと推察している．このように，トロール曳網において漁獲量や漁獲物組成に昼夜による差が生じる要因は生理的あるいは生態的なもの等多様であると考えられるが，底魚資源研究のために行われるトロール調査においては，昼夜によって漁獲に差が生じることを充分認識しておく必要がある．このことは特に，昼夜差の著しい種の資源状態の検討において重要であり[3,11]，昼間曳網と夜間曳網が混在する時には，Table 2 に示したような昼夜比を基に調査結果を補正して用いることもひとつの方法であろう．また，底びき網漁業の漁船操業記録や漁獲統計の分析に当たっては，操業の際の昼夜の別を考慮する必要がある．さらに，これらの分析の精度向上のためには，トロール曳網による昼夜の漁獲差についての知見を蓄積することが望まれる．

文　献

1）B. B., Parrish, J. H. S. Blaxter and W. B. Hall 1964：Diurnal variations in size and composition of trawl catches. *Rapp. Cons. Explor. Mer*, **155**, 27-34.

2）S. J. Walsh 1988：Diel variability in trawl catches of juvenile and adult yellowtail flounder on the Grand Banks and the effect on resource assessment. *North Amer. J. Fish. Manag.*, **8**, 373-381.

3）永井達樹　1989：トロール調査による魚類の豊度推定値の精度について．遠洋水産研究所研究報告，(26)，13-20.

4）佐々木幸康・小池　篤　1959：トロール網に入る2，3の水族の昼夜間による漁獲差について．日本水産学会誌，**25**(2)，111-116.

5）最首光三・小島喜久雄　1960：東海・黄海にお

ける底棲魚類の生態—I．垂直移動について．西海区水産研究所研究報告，(19)，1-13．

6）最首光三　1969：東シナ海，黄海産キグチの垂直移動の日周期性について．日本生態学会誌，**19**(1)，13-20．

7）山田純三郎　1964：東海黄海の底びき網漁船の主要魚種の漁獲について．底魚資源調査研究連絡（西海区水産研究所），(29)，1-12．

8）山田純三郎　1970：東海黄海の底びき網漁船のマナガツオの漁獲について．底魚資源調査研究連絡（西海区水産研究所），(65)，1-9．

9）神田献二　1949：龍田丸に於ける漁獲組成の昼夜に依る差異．東海黄海底魚資源調査研究誌（水産庁福岡駐在所，水産研究会福岡分室共編），**1**，9-11．

10）松岡正信・谷口順彦・藤田　矗・北島忠弘・時村宗春　1989：東シナ海・黄海産メイタガレイ類の比較研究—I．分布，形態及び遺伝的差異．西海区水産研究所研究報告，(67)，23-36．

11）L. K. Boerema　1964：Some effects of diurnal variation in the catches upon estimates of abundance of plaice and sole. *Rapp. Cons. Explor. Mer*, **155**, 52-57.

Reproduction of the Freshwater Stingray, *Potamotrygon magdalenae* Taken from the Magdalena River System in Colombia, South America

Kazuyuki TESHIMA* and Koji TAKESHITA**

ABSTRACT

Reproductive biology of the freshwater stingray, *Potamotrygon magdalenae* was examined while conducting research on freshwater elasmobranchs in Colombia, South America from August 12 through August 19, 1980. A total of 117 *P. magdalenae* specimens (female; 44, male; 73) were taken by gillnet in lakes near the Magdalena River system in the northern Colombia. After measuring and observing external characteristics of the stingrays, reproductive organs removed were preserved in formalin and brought to Japan for histological observations. Unlike many other female elasmobranchs, oogenesis in *P. magdalenae* was characterized by unusual folds that were formed on the follicular epithelium. The follicular epithelial folds, that extended inward into the oocyte, filled the oocyte before it reached the maturity. After ovulation, the follicular epithelial folds were freed from the mature oocyte and remained in the postovulatory follicle. Ovulation appears to occur when the oocyte reaches the diameter of about 25 mm. *P. magdalenae* has a non-placental viviparous mode of reproduction and a single embryo develops in each uterus. Size at birth for the embryos is estimated to be about 100 mm in disk width. *P. magdalenae* is estimated to reach the maturity between 170 and 210 mm disk width in females and between 170 and 190 mm disk width in males. Based on the development of ovaries and testes, the size of embryos found in uteri, and the estimated size at birth, the reproductive activity including ovulation, mating, fertilization, and parturition might take place over an extended period of time, therefore suggesting that *P. magdalenae* might not have a definitive reproductive season.

INTRODUCTION

During a visit to Colombia we had the opportunity to make a large collection of the

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freshwater stingray, *Potamotrygon magdalenae* and to study its reproductive biology. *Potamotrygon magdalenae* is one of about 20 species of the Potamotrygonidae that are restricted to the freshwaters of South America[1]. In this study we report on aspects of the reproductive biology, including oogenesis, spermatogenesis, size at maturity, and size at birth of this species.

MATERIALS AND METHODS

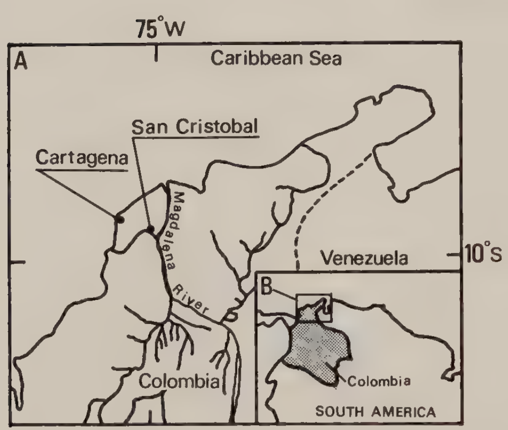


Fig. 1. Freshwater stingray, *P. magdalenae* were taken in lakes near San Cristobal in Colombia. Rivers and lakes around San Cristobal constitute the Magdalena River system. A is a magnification of B.

During the period from August 12 through August 19, 1980, we sampled 117 individuals of freshwater stingray, *Potamotrygon magdalenae* in lakes near San Cristobal, a small village located about 150 km southeast of Cartagena in Colombia, South America (Fig. 1). With assistance of local fishermen, stingray samples were taken by gillnet in lakes constituting the Magdalena River system.

After measuring and observing external characteristics of the stingrays, reproductive organs were removed, preserved in formalin, and brought to Japan for histological observations. Paraffin sections were made of ovaries and testes and stained with Haematoxylin and eosin.

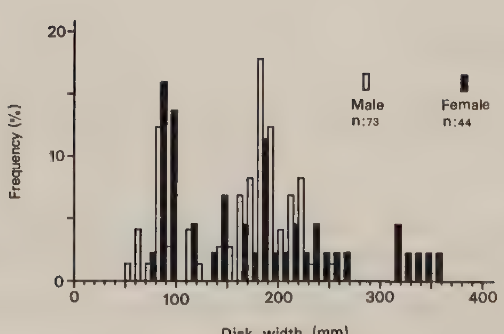


Fig. 2. Size composition of *P. magdalenae* specimens used as study material.

RESULTS

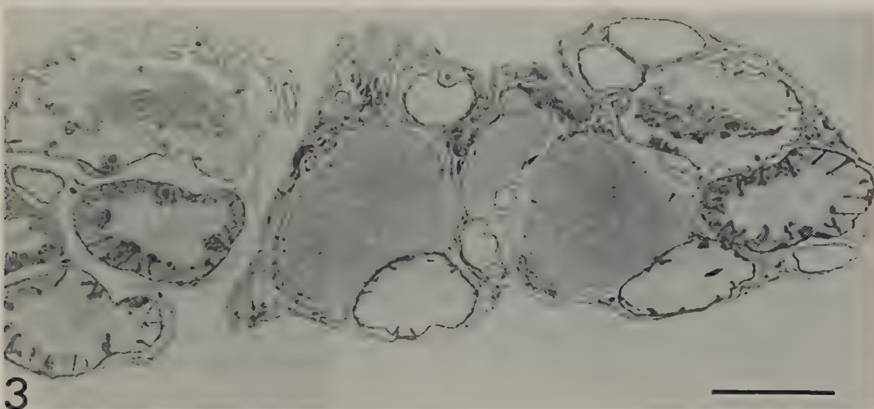
Sample size

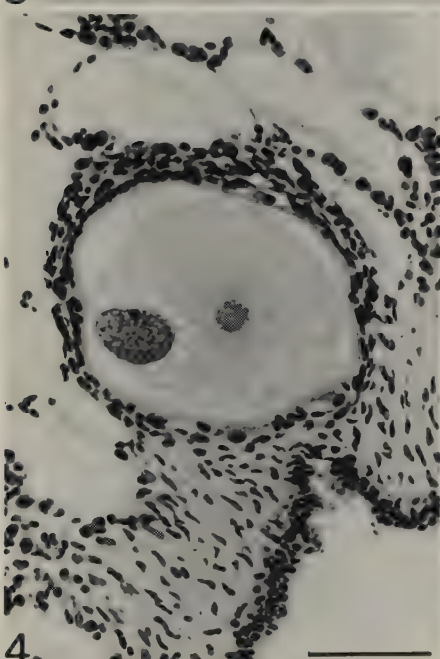
The 117 *P. magdalenae* specimens used in the study consisted of 44 females ranging from 73 to 357 mm disk width and 73 males from 52 to 253 mm disk width (Fig. 2). No males greater than 260 mm disk width were sampled. Twenty-one smaller speci-

mens between 58 and 97 mm disk width retained small-sized external yolk sacs.

Female

Reproductive organs of female *P. magdalenae* consisted of a functional pair of ovaries, oviducts, nidamental glands, and uteri. In many other elasmobranchs a common ostium to receive ovulated eggs is formed near the ventral side of the esophagus by the fusion of the anterior ends of the right and left oviducts. However,





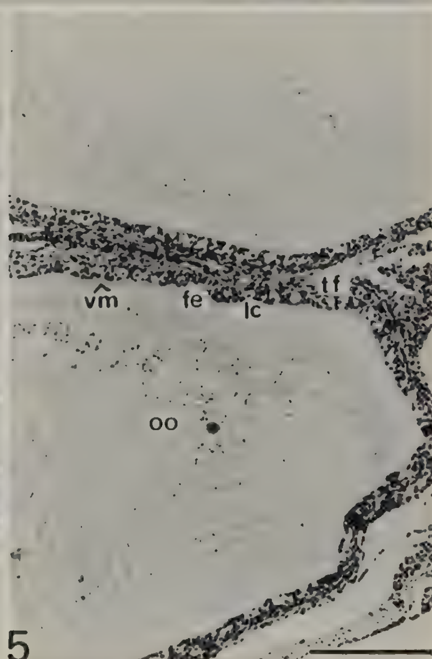


Fig. 3. Transverse section of *P. magdalenae* ovary. Scale bar: 6.5 mm.

Fig. 4. Oocyte at early developmental stage. Scale bar: 320 μm.

Fig. 5. Enlarged cells seen in the follicular epithelium. Scale bar: 250μm, fe: follicular epithelium, lc: enlarged cell, oo: oocyte, tf: theca folliculi, vm: vitelline membrane.

in *P. magdalenae* the ostium was formed independently at the anterior end of the each oviduct, i. e., the right and left common ostia were separate.

Ovary and oogenesis

Free surface of the ovary was covered with one or two layers of cuboidal epithelial cells. The epithelium was underlaid by fibrous connective tissue continuous with the medulla (Fig. 3). Oocytes at the earliest developmental stage were lined by a single layer of cuboidal cells (Fig. 4). When the oocytes reached 8 to 10 mm in diameter (Fig. 5), they were lined with a single layer of columnar cells. The follicle at this stage was composed of the oocyte, vitelline membrane, follicular epithelium, and theca folliculi including the fibrous connective tissue. An inner and an outer layer was distinguishable in the theca folliculi At the 8 to 10 mm stage, enlarged cells were observed in the follicular epithelium and part of the follicluar epithelium began to form fold like processes (Fig. 5). Oocytes at the 10 to 15 mm in diameter stage had large follicular epithelial folds that extended inward into the oocyte (Fig. 6). With further development, the enlarged cells in the epithelium increased in number. Oocytes at the 20 mm stage were filled with extended epithelial folds (Fig. 7). The folds had fibrous connective tissue that extended from the theca folliculi (Figs. 8, 9). The clearly visible vitelline membrane intervened between the oocyte and the epithelial folds (Figs. 8, 9). Ovulation appeared to occur when the oocyte reached the diameter of about 25 mm.

The follicular epithelial folds that filled the oocyte remained in the postovulatory follicle after ovulation (Fig. 10), often with several epithelial folds protruding from the postovulatory follicle (Fig. 12). During ovulation, the oocyte appeared to be extruded through the portion where the follicular folds protruded (Fig. 10). Both follicular folds that remained within the postovulatory follicle (Fig. 11) and those that protruded through the surface of the postovulatory follicle (Fig. 13) had proliferated cells.

Ovaries, in which ovulation appeared to have just occurred, were found in the two stingrays of 310 mm disk width. One of the two stingrays that had ovaries showing sings of ovulation had a large egg, greater than 50 mm in diameter, in the left common ostium (Fig. 14). This egg was over twice the size of the larger oocytes observed in this study.



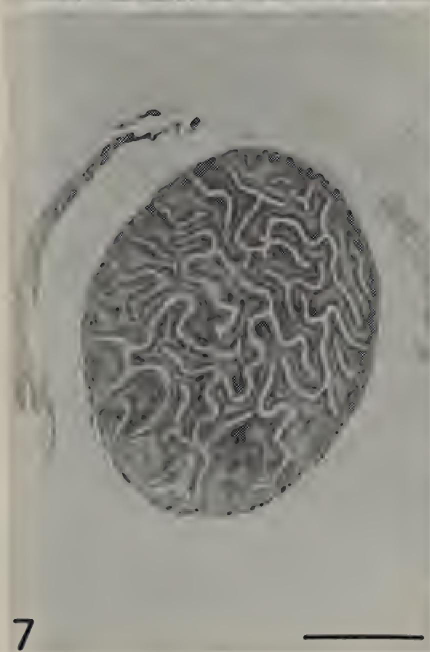


Fig. 6. Follicular epithelial folds. Scale bar: 250 μm.

Fig. 7. Nearly mature oocyte filled with extended follicular epithelial folds. Scale bar: 6.5 mm.



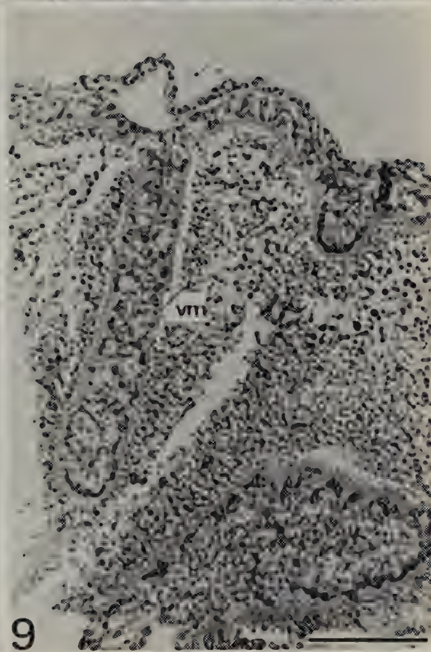


Fig. 8. Developed follicular epithelial folds. Scale bar: 250 μm, vm: vitelline membrane.

Fig. 9. Enlarged cells well developed in the follicular epithelial folds. Scale bar: 0.65 mm, vm: vitelline membrane.

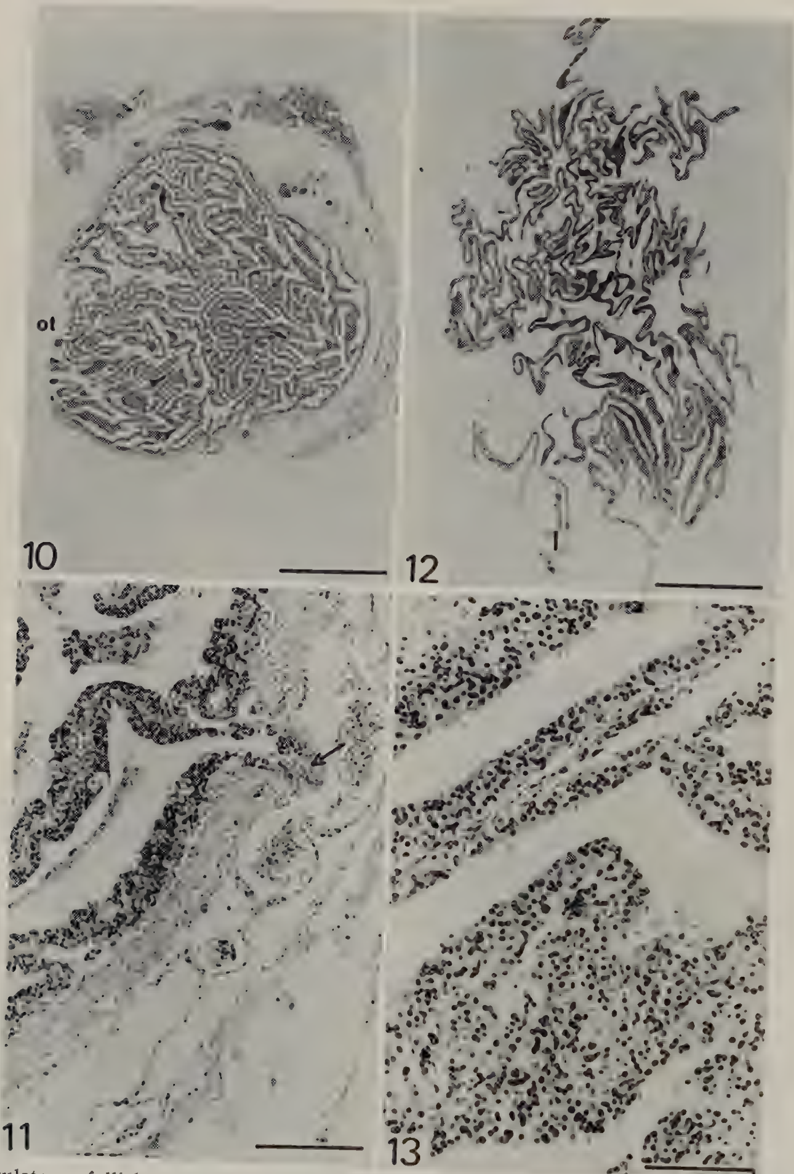


Fig. 10. Postovulatory follicle in which follicular epithelial folds were left. An oocyte appeared to be ovulated through the portion shown as ot in the photograph. Scale bar: 6.5 mm.

Fig. 11. Enlarged photograph of Fig. 10. Follicular epithelial cells proliferated and part of them abutted on the outerlying connective tissue through the theca folliculi shown as an arrow. Scale bar: 250 μm.

Fig. 12. Follicular epithelial folds protruded outward through the surface of the postovulatory follicle (see Fig. 26-5). Scale bar: 6.5 mm.

Fig. 13. Enlarged photograph of Fig. 12. Cells in the folds proliferated. Scale bar: 130 μm.

Embryos

The two stingrays bearing embryos suggest that this species is non-placental viviparous, as defined by TESHIMA,[2] and that a single embryo develops in each uterus (Fig. 15). One 210 mm disk width female stingray had a 42 mm and a 46 mm disk width embryo in the right and left uteri respectively. The other 240 mm disk



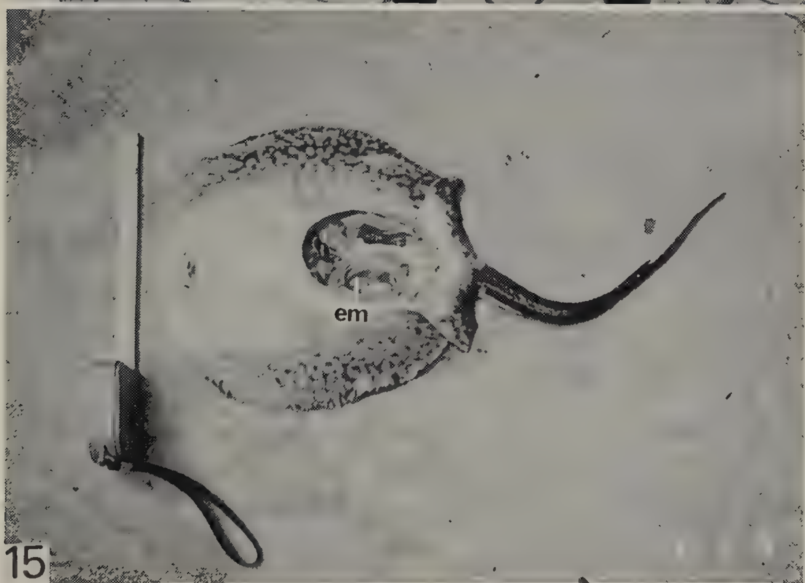


Fig. 14. An ovulated egg (oe) was seen being received through the left common ostium of *P. magdalenae* of 310 mm in disk width.

Fig. 15. A pregnant *P. magdalenae* (240 mm-disk width) with the embryo (em).

width female had a 68 mm disk width embryo in each uterus. A male embryo of 68 mm disk width had its head pointing posteriorly in the uterus while another male 46 mm disk width had its head directing anteriorly in the uterus. All four embryos had their left pectoral fin bent ventrally in contact with the external yolk sac and their right pectoral fin bent dorsally (Fig. 15).

Oocyte diameter-disk width relationship

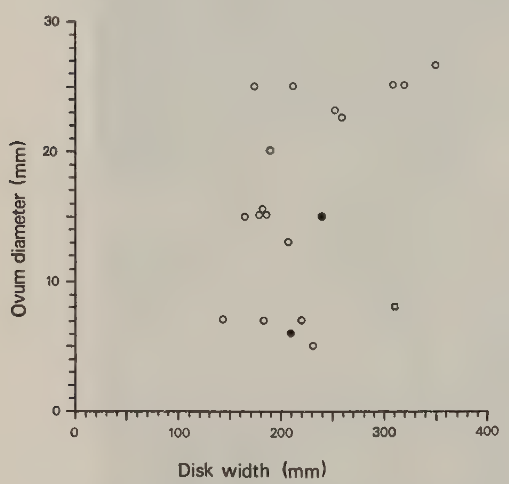


Fig. 16. Relationship between ovum diameter and disk width. Closed circle indicates pregnant female.

The largest oocyte in females ranging from 150 to 350 mm disk width was 5 to 25 mm in diameter (Fig. 16). Oocytes larger than 20 mm were found in stingrays between 170 and 350 mm disk width. The largest oocytes in females with embryos were 6 and 15 mm. Female stingrays smaller than 150 mm disk width had minute oocytes and thread-like uteri.

Small-sized individuals

The 21 smaller *P. magdalenae*, ranging from 58 to 97 mm disk width retained external yolk sacs. The four smallest of these, 58 to 62 mm disk width, had external yolk sacs as large as the embryos in the uteri of the 240 mm disk width female. The 17 larger individuals, 77 to 97 mm disk width, had yolk sacs ranging from 1 mm in diameter to 2 mm in width and 6 mm in length.

Male

Reproductive organs of male *P. magdalenae* consisted of a pair of testes, epididymis, spermiducts, seminal vesicles, and claspers.

Testis and spermatogenesis

The testis of *P. magdalenae* was composed of five or six to 15 or 16 testicular masses (Fig. 17). Each of testicular masses was separated by connective tissue and was occupied by numerous seminiferous follicles in which spermatogenic cells were developing (Fig. 17). Initial development of spermatogenic cells occurred in semi-

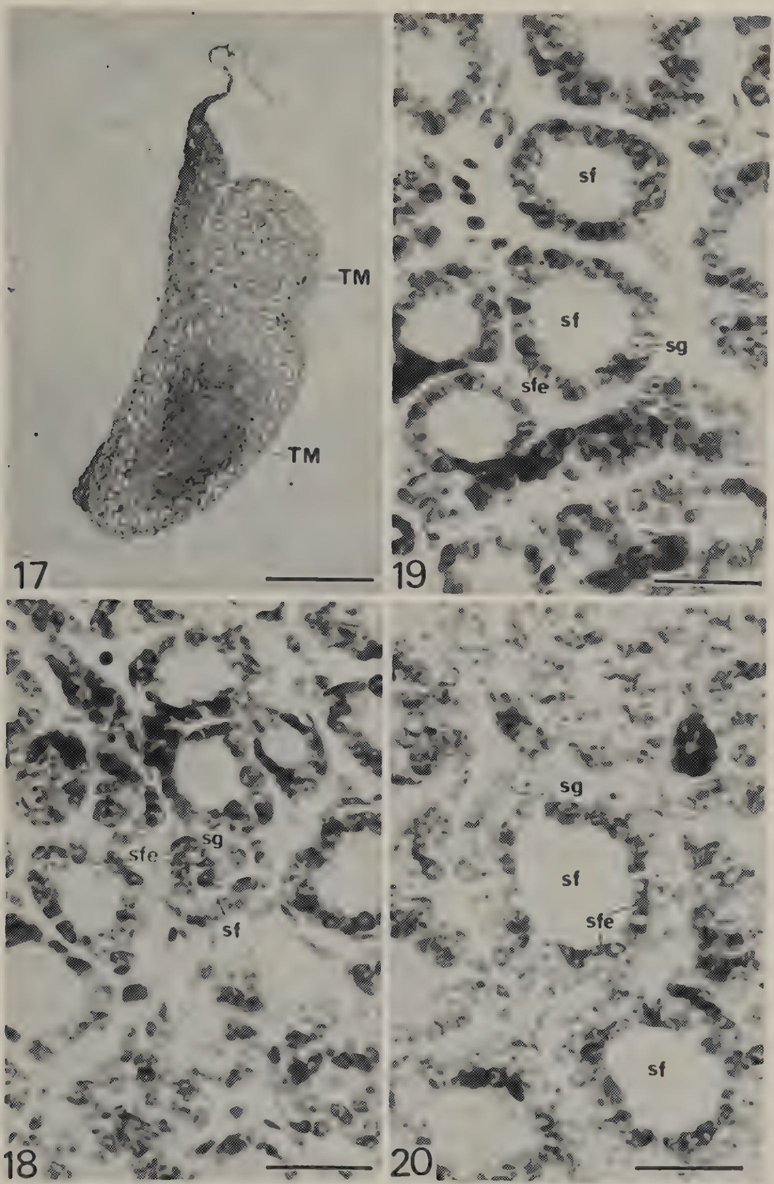


Fig. 17. Testicular masses (TM) showing seminiferous follicles at varying developmental stages. Scale bar: 2.5 mm.

Fig. 18. Seminiferous follicle (sf) at the earlier stage consisted of a spermatogonium (sg) and seminiferous epithelial cells (sfe). Scale bar: 30 μm.

Fig. 19. Seminiferous follicle (sf) at this stage was lined by a single layer of cells composed of spermatogonia (sg) and seminiferous epithelial cells (sfe). Scale bar: 30 μm.

Fig. 20. Seminiferous follicle(sf) at this stage was lined by two layers of cells composed internally of seminiferous epithelial cells(sfe) and externally of spermatogonia (sg). Scale bar: 30 μm.

niferous follicles within the center of the testicular masses and mature spermatogenic cells were observed in seminiferous follicles located at the periphery of the testicular masses (Fig. 17).

In the early development, the seminiferous follicle was composed of a single spermatogonium surrounded by the several seminiferous epithelial cells (Fig. 18). Spermatogonia and seminiferous epithelial cells developed by repeated division into a seminiferous follicle with an intrafollicular space (Fig. 19). At this stage, the seminiferous follicle was covered with a single layer of spermatogonia and follicular epithelial cells (Fig. 19). With further development a single layer of cells covering the follicle differentiated into two layers of cells (Fig. 20). The internal layer was formed by seminiferous epithelial cells and the external one by spermatogonia (Fig. 20). As spermatogonia proriferated in number, seminifereous epithelial cells, which formed the internal layer of the follicle, appeared to be forced inward (Fig. 20). Having reached this developmental stage, one spermatogonium formed a cyst in which spermatogenesis took place (Fig. 21). Spermatogonia developed into spermatocytes, spermatocytes into spermatids, and spermatids finally into spermatozoa (Fig. 22). As the final developmental stage of spermatogenesis about 50 to 60 spermatozoa, which originated in one spermatogonium, gathered to form a sperm clump (Fig. 23). As in many elasmobranchs, the head of spermatozoa of *P. magdalenae* was spiral in shape and spermatozoa had their heads directing toward the basement membrane of seminiferous follicles (Fig. 23). Sertoli cells were seen to locate near the head of spermatozoa (Fig. 23).

Spermatozoa produced in the testis were transferred into the epididymis through the collecting ducts located in the periphery of the testicular mass (Fig. 24). The internal surface of the collecting duct was lined by a single layer of cuboidal cells. Beneath the epithlium fibrous connective tissue existed (Fig. 24). Spermatozoa, which were transported through the epididymis and the spermiduct, were stored in the seminal vesicle.

With a few exceptions, male *P. magdalenae* greater than 170 mm disk width had seminal vesicles that were filled with spermatozoa. Gentle pressure on the seminal vesicles caused these males to extrude spermatozoa from the urinogenital papilla. Males between 150 and 170 mm disk width had seminal vesicles that were filled partially with spermatozoa or had slender seminal vesicles. Males between 110 and 130 mm disk width had thread-like precursor seminal vesicles.

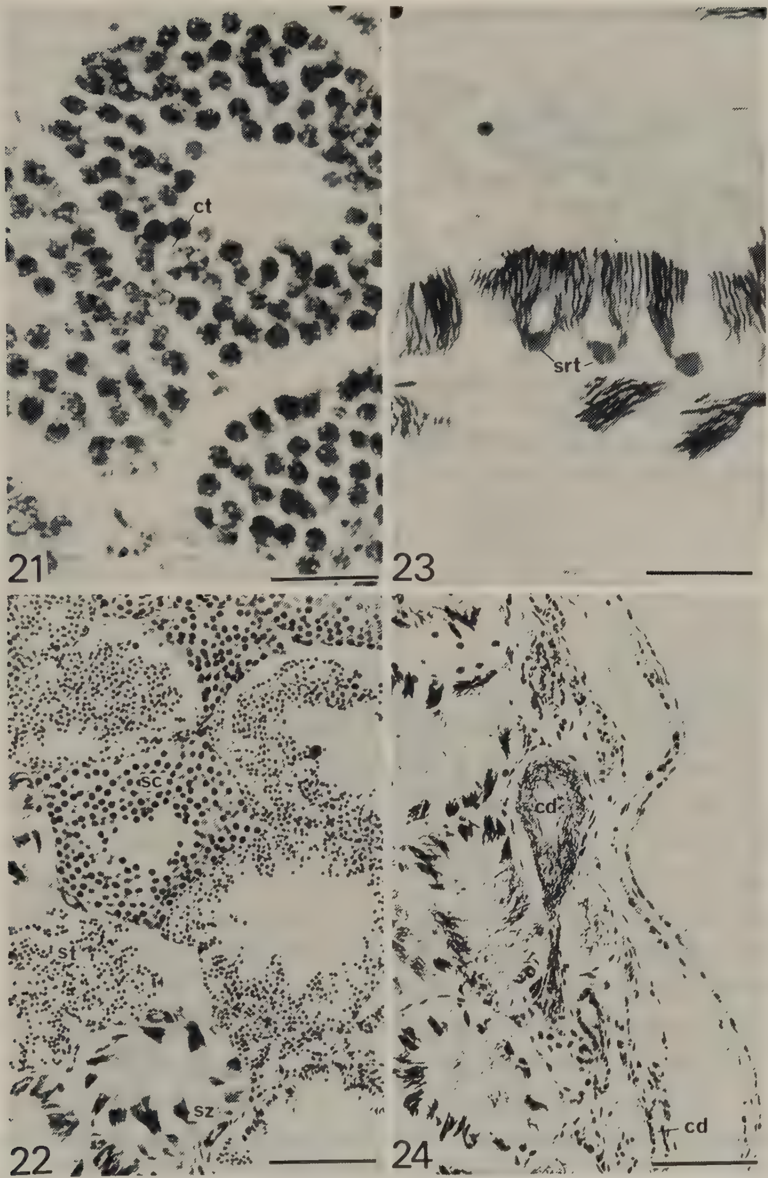


Fig. 21. One spermatogonium formed a cyst (ct) in which spermatogenic cells developed. Scale bar: 30 μm.

Fig. 22. Spermatogonia developed into spermatocytes (sc), into spermatids (st), and finally into spermatozoa (sz). Scale bar: 130 μm

Fig. 23. Mature spermatozoa. Sertoli cells (srt) were seen near the head of spermatozoa. Scale bar: 30 μm.

Fig. 24. Collecting duct (cd) through which spermatozoa were transported into the epididymis. Scale bar: 130 μm.

Clasper length-disk width relationship

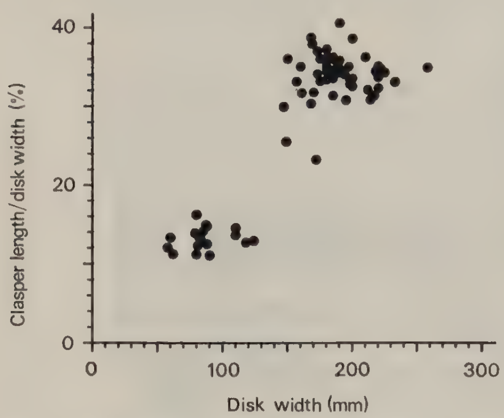


Fig. 25. Relationship between clasper length and disk width.

Clasper growth was very asymmetrical in relation to body length (Fig. 25). They showed only a slight increase is size in males less than 120 mm disk width, showed a rapid increase in size in males between 120 and 150 mm disk width, and grew slightly in males over 190 mm disk width.

DISCUSSION

Oogenesis in *P. magdalenae* differs from that of many elasmobranchs[3] in that follicular epithelial folds extended inward into the oocyte and enlarged cells were formed in the extending follicular epithelium. This type of oogenesis is similar to that in *Urolophus halleri* described in Babel.[4] Developmental stages up to ovulation are similar in the two species. However, unlike *P. magdalenae*, in which the follicular epithelial folds remained in the postovulatory follicle after ovulation, in *U. halleri* the follicular epithelial folds remain in the ovulating oocyte, and only the theca externa, which surrounds the oocyte, remains in the postovulatory follicle.[4] Babel[4] stated that the corpus luteum in *U. halleri* is not derived from the follicular epithelium as in a number of elasmobranchs, some viviparous reptiles, and in mammals but that it appears to arise from the theca externa which remains in the postovulatory follicle. However, in *P. magdalenae*, the corpus luteum-like tissue is thought to originate from the follicular epithelial folds that are left in the postovulatory follicle as shown by the proliferations of follicular epithelial cells left in the postovulatory follicle (Fig. 11). The developmental process of the oocyte observed and described for *P. magdalenae* is summarized in Fig. 26.

Largest oocytes found in ovaries were up to 25 mm in diameter (Fig. 16), indicating that in *P. magdalenae* ovulation appears to occur when the oocyte reaches the diameter of about 25 mm.

The enlarged cells, which were formed in the follicular epithelial folds of *P. magdalenae*, are also described for *U. halleri*.[4] Babel[4] stated that the inclusions

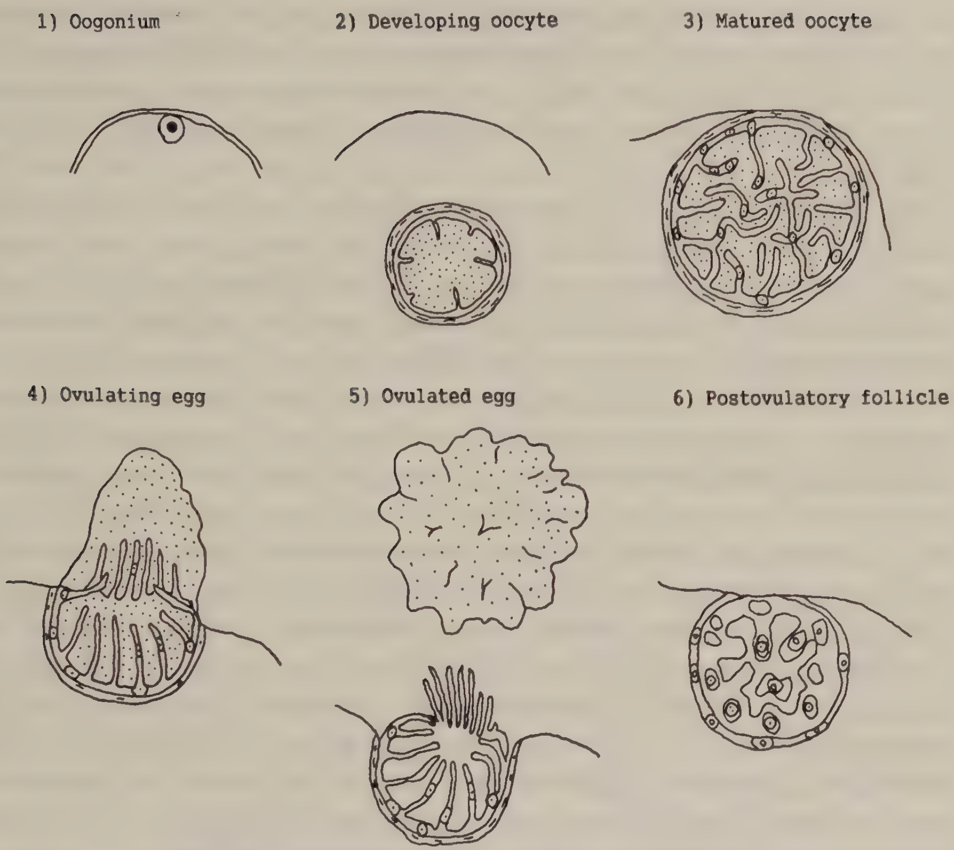


Fig. 26. Developmental stages of oocyte in *P. magdalenae.*

contained in enlarged cells are structurally identical to the yolk granules of the oocyte and concluded that the enlarged cells in *U. halleri* appear to synthesize and transport yolk as do follicle and nurse cells of some invertebrates. WALLACE[5] also mentioned that cells of the extended follicular epithelium appear to function as nutrient cells.

Eggs apparently doubled in size after ovulation because largest oocytes in the ovaries were 25 mm diameter and eggs entering the common ostium were over 50 mm diameter (Fig. 14). The increase in size is due to that follicular epithelial folds, which extended far into the egg's center, amplified the surface area of the oocyte when ovulation occurred. The reason for the increase of the egg size is unknown, but apparently is rare in elasmobranchs.

Females larger than 170 mm disk width appear to have either nearly reached or to have reached maturity because they contained oocytes about 25 mm in diameter (Fig. 16) and the 210 and 240 mm disk width females had embryos in their uteri (Fig. 15).

Females less than 150 mm disk width had ovaries with minute oocytes and thread-like uteri. Thus, female *P. magdalenae* appears to reach the maturity between 170 and 210 mm disk width. Also, DAHL,[6] in a study of fishes in the northern Colombia stated that this species reaches the maturity before they attain 25 cm in length.

The 21 smaller specimens between 58 to 97 mm disk width had small-sized external yolk sacs and the smallest four individuals (58 to 62 mm disk width) appeared to have been aborted by their mothers during capture because their body size and external yolk sacs were the size of those embryos found in the uteri of two female *P. magdalenae*. More than the half of the individuals between 85 and 97 mm disk width had minute external yolk sacs which lacked yolk. The smallest individual without an extenal yolk sac but with a yolk stalk scar was 80 mm disk width, suggesting that individuals between 85 and 97 mm disk width, with minute external yolk sacs, were the nearly full-term embryos. Thus, parturition appears to occur before embryos attain 100 mm disk width. Embryos, bearing an external yolk sac in which yolk still remained, appear to have extruded from uteri when they were caught.

In many other elasmobranchs seminiferous follicles shift from one side toward the other side as spermatogenic cells develop.[7] In *Mustelus manazo* and *M. griseus* seminiferous follicles containing spermatogenic cells at the earlier stage are located in the ventral side of the testis but those containing mature sermatogenic cells are located in the dorsal side. Apparently, seminiferous follicles move from the ventral toward the dorsal sides as spermatogenic cells develop.[8] However, in *P. magdalenae* seminiferous follicles moved from the central area toward the periphery of testicular masses as spermatogenic cells developed.

In male elasmobranchs clasper growth is very asymmetrical in relation to body growth and claspers tend to grow slightly after males attain the maturity. In *P. magdalenae* claspers showed a rapid increase in size in males between 120 and 150 mm disk width and grew slightly in males over 190 mm disk width. Males greater than 170 mm disk width had seminal vesicles that were filled with spermatozoa and gentle pressure on the seminal vesicles caused those males to extrude spermatozoa from the urinogenital papilla. Growth pattern in claspers, in addition to development of the seminal vesicles, suggests that male *P. magdalenae* becomes mature and sexually active at 170 to 190 mm disk width.

One objective of this study was to determine reproductive periodicity in *P. magdalenae*, i. e., reproductive activity occurs throughout the year or is limited to periods during the year. Indices used commonly to determine the reproductive cycle for elasmobranchs are developmental condition of oocytes, the growth condition of embryos in the uterus, and spermatozoa-condition (presence or absence) in

the seminal vesicle. The growth condition of embryos is often used. For example, in *Carcharhinus dussumieri*, which occurs off northern Borneo, embryos at varying developmental stages from the fertilized eggs to the nearly full-termed embryos are found in uteri of females taken during a week-long sampling period. It is, therefore, determined that the reproductive activity for *C. dussumieri* occurs throughout the year.[9] The same phenomenon is also shown in *Scoliodon laticaudus* which occurs in the western waters off Malaysia.[10] Contrary to this, in species which have a definitive reproductive season the embryos in uteri of female samples taken in the same time are usually the same size. For example, in the two species of the genus *Mustelus*, which occur in the waters around Japan, ovulation and mating take place from June through August and embryos of about 300 mm total length are born during the next April through May.[8] Female samples taken in the same time, e. g., in January or February have the embryos at about 250 mm total length.[8]

In *P. magdalenae*, four embryos were found in uteri of the two females and possibly nearly full-termed embryos were found during a eight-day sampling period. The four embryos found in the uteri were 42, 46, 68, and 68 mm disk width, and the full-termed embryos were 85 to 97 mm disk width. Size at birth for *P. magdalenae* embryo is estimated to be about 100 mm disk width. Based on these observations, *P. magdalenae* embryos are assumed to have been at the different developmental stages although the sampling period was very short. It is, therefore, suggested that the reproductive activity including ovulation, mating, fertilization, and parturition might take place over an extended period of time and that *P. magdalenae* may not have a definitive reproductive season. For the present study, however, the reproductive cycle such as the mating period, gestation period, embryo delivering period, could not be determined.

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REFERENCES

1) T. B. Thorson 1970 : Freshwater stingrays, *Potamotrygon* spp. : Failure to concentrate urea when exposed to saline medium. *Life Sci.*, **9**(II), 893–900.

2) K. Teshima 1984 : Reproduction. In "Sharks, Skates, and Rays as Living Resources" (ed. by T. Taniuch and M. Suyama), Suisangaku Series 49, 9–20, Kouseisha Kouseikaku, Tokyo. (In Japanese)

3) J. P. Wourms 1977 : Reproduction and development in chondrichthyan fishes. *Amer. Zool.*, **17**, 379-410.

4) J. S. Babel 1967: Reproduction, life history, and ecology of the round stingray, *Urolophus halleri* Cooper. *Calif. Dept. Fish and Game, Fish Bull.*, **137**, 1–104.

5) W. Wallace 1903 : Observations on ovarian ova and follicles in certain teleostean and elasmobranch fishes. *Quart. J. Mic. Sci.* n. s., **47**, 161–213.

6) G. Dahl 1971 : Los peces del norte de Colombia. Instituto de Desarrollo de los Recursos Naturales Renovables. Ministerio de Agricultura, Colombia, pp. 391.

7) H. P. Stanley 1966 : The structure and development of the seminiferous follicle in *Scyliorhinus caniculus* and *Torpedo marmorata* (Elasmobranchii). *Zeit. Zellforsch.*, **75**, 453–468.

8) K. Teshima 1981 : Studies on the reproduction of Japanese smooth dogfishes, *Mustelus manazo* and *M. griseus*. *J. Shimonoseki Univ. Fish.*, **29** (2), 113–199.

9) K. Teshima and K. Mizue 1972 : Studies on sharks–I. Reproduction in the female sumitsuki shark, *Carcharhinus dussumieri*. *Mar. Biol.*, **14**(3), 222–231.

10) K. Teshima, M. Ahmad and K. Mizue 1978 : Studies on sharks–XIV. Reproduction in the Telok Anson Shark collected from the Perak River, Malaysia. *Japan. J. Ichthyol.*, **25** (3), 181–189.

南アメリカ，コロンビアのマグダレーナ河で採集した淡水エイ，*Potamotrygon magdalenae* の生殖

手島　和之・竹下　貢二

抄　　録

1980年８月12日から８月19日の間，淡水産板鰓類の生物学的調査を行うために滞在した南アメリカ，コロンビア北部のマグダレーナ河水系において，117（雌:44;雄:73）尾の淡水エイ，*Potamotrygon magdalenae* を刺網で捕獲することができた．採集した標本の外部形態の測定・観察を行った後，生殖腺を取り出しホルマリンで固定し，日本に持ち帰り組織切片を作成し，観察した．*P. magdalenae* の卵形成は，他の板鰓類と異なり，発達の途中で卵胞上皮に形成された襞状突起物が卵細胞の発達とともに卵細胞内に伸展し，成熟に達する頃までに細胞内を埋め尽くすような特異な発達過程を示した．排卵後，卵胞上皮の襞は卵細胞より離れ卵胞内に留まっているのが観察された．排卵時の卵細胞の大きさは直径で約 25㎜ であった．*P. magdalenae* の生殖様式は，非胎盤型胎生で，一つの子宮内に一尾の胎児が成長する単胎であった．出産時の胎児の大きさは体盤幅でおよそ 100㎜ であった．雌は体盤幅170〜210㎜ で，雄は170〜190㎜ の間で成熟すると推定された．雌雄生殖腺の発達状態，子宮内胎児の大きさ，出産時の胎児の大きさから，*P. magdalenae* は特定の生殖時期をもたず，一年の内比較的長期間に亘り，交尾，出産等の生殖行動を行うと推定された．

志々伎湾におけるヒラメ放流種苗の減耗過程

首藤 宏幸*・後藤 常夫**・池本 麗子*,***
冨山 実****・畔田 正格*****

Mortality of Reared Flounder (*Paralichthys olivaceus*) Juveniles Released in Shijiki Bay

Hiroyuki SUDO*, Tsuneo GOTO**, Reiko IKEMOTO*,***,
Minoru TOMIYAMA**** and Masanori AZETA*****

ABSTRACT

Experimental releases of 37,000 (33.7 mm TL) and 24,600 (81.2 mm TL) reared flounder juveniles were carried out in Shijiki Bay in 1985 and 1986, respectively, to elucidate the process and mechanism of their mortality. Total numbers of recaptured fish were 577 and 450 in 1985 and 1986, respectively, and most of them were caught within 10 days after release. Decrease rates of released fish were therefore high in both years (17.6%・day^{-1} in 1985 and 45.1%・day^{-1} in 1986). However, the process of their decrease and adaptation was different. In 1985 : (1) the decrease rate of small fish (TL<35 mm) was higher than that of large ones ; (2) albinic fish decreased more rapidly than normal ones; and (3) feeding incidence was low. In 1986 : (1) there was no difference in decrease rate between small (TL<75 mm) and large fish; (2) decrease patterns were similar between albinic and normal fish; and (3) feeding incidence was high. These results suggest that the most significant cause of decrease of released fish was predation in 1985 and dispersal in 1986, because it is easy for predators to catch and handle small and starving fish and to detect albinic fish.

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は じ め に

ヒラメ人工種苗の量産化の実現以来，種苗放流を中心としたヒラメの資源培養の可能性が検討され始めた．各地で実施されたヒラメ種苗の放流追跡調査結果は，種苗の急激な減耗が放流直後に起こることを指摘している[1),*,**]．しかし，その減耗要因については必ずしも特定できているとは言い難い．ヒラメの資源培養を推進するには効果的な放流方法の開発が必要であり，そのためにはまずヒラメ放流種苗の減耗過程を把握しその要因を明らかにすることが急務である．

私たちは長崎県平戸島志々伎湾において，1982年以来天然ヒラメ当歳魚の生態調査を実施し，その接岸・着底過程[2-4)]，着底直後の減耗過程[5)]，着底後の生活様式[6,7)] 等を明らかにしてきた．これらの天然ヒラメの生残過程に関する知見を基礎に，1984年から1988年までの5年間には放流種苗の順化・減耗過程を把握するために，全長の異なるヒラメ人工種苗計70,000尾を放流し追跡調査を実施した．ヒラメ放流種苗の再捕は放流直後の急激な減耗により短期間であったが，その減耗要因については二，三の知見が得られた．

本報告では，ヒラメ放流種苗の個体数の減少傾向を，その全長および白化の程度に注目して解析する．さらに，この減少傾向を種苗の移動，摂餌，被食状況と関連づけて検討することにより，放流直後の減耗要因の特定を試みる．あわせて，放流種苗が他魚種に与える影響についても言及する．

本論に入るに先立ち，研究遂行上種々の御援助・御助言を賜った三重大学の松宮義晴教授，長崎大学の東幹夫教授，京都大学の田中　克助教授に感謝する．また，当所の輿石裕一室長には論議に加わって頂いた．厚く御礼申し上げる．さらに，現地調査に際し多くの便宜を計って頂いた志々伎湾漁業協同組合の方々，ヒラメ種苗の放流・追跡とその処理・分析に御協力頂いた長崎大学および京都大学の多くの学生諸君，当所の田中徳子氏に深謝する．最後に，マリーンランチング計画ヒラメ・カレイ研究グループのリーダーとして，また志々伎湾調査のリーダーとしてその指導性をいかんなく発揮された当時の西海区水産研究所加藤史彦室長に心から感謝の意を表する．

本研究の一部は，農林水産技術会議大型別枠研究「近海漁業資源の家魚化システムの開発に関する総合研究」によった．

方　　法

志々伎湾におけるヒラメ人工種苗の放流および追跡調査は，1984年から1988年の5年間にわたり実施された．ただし，本報告では，その順化・減耗過程の解析に十分な再捕尾数が得られた1985年と1986年の2ケ年の結果についてのみ検討した．

1．ヒラメ人工種苗の放流

1985年および1986年の種苗放流は，それぞれ，4月24日および5月10日に実施された．1985年では37,000尾（平均全長±標準偏差：33.7±8.35mm）の人工種苗を湾奥部渚域の田の浦（水深約1.5m）に，1986年には24,600尾（81.2±12.80mm）の人工種苗を湾奥部砂底域の G-2（水深約12.0m）に放流した（Fig. 1）．放流場所は，放流種苗の全長と天然ヒラメの成長にともなう移動様式――渚域に着底したヒラメ稚魚は成長とともに沖合域へ移動する――とを考慮して選定した．なお，両放流点の底質の中央粒径値（$Md\phi$）は2～3の細砂であり[8,9)]，田の浦には4～5月に極めて高密度の天然ヒラメ稚魚が着底し[2-5)]，G-2 には6～10月にマダイ幼稚魚が集中分布する[10)]．

ヒラメ種苗の海底への放流方法は，水深が浅い田の浦においては船上から直接放流し，一方，水深の深いG-2 では種苗を入れた放流ケージを海底まで降下後，ケージを開口して放流した．なお，人工種苗は無標識で放流したが，天然ヒラメとはその体色（有眼・無眼側の体色異常）および全長――湾内では全長30mm以上の天然ヒラメがほとんど採集されない[4,5)] ――により容易に識別可能であった．

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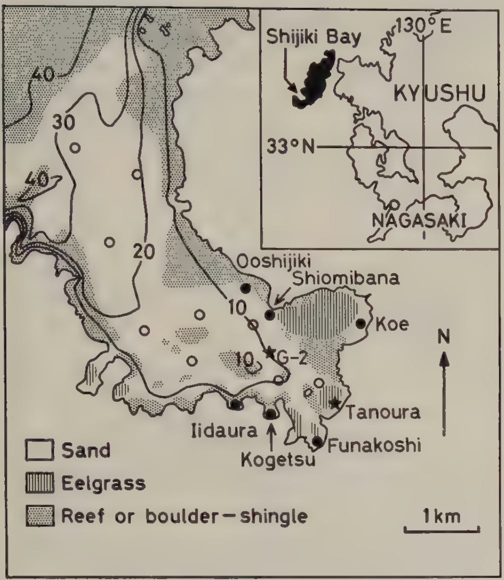


Fig. 1. 志々伎湾におけるヒラメ種苗の放流点（★）と桁網（●）および底びき網（○）による採集定点．図中の数字は水深を示す
Release stations of flounder (★) and sampling stations of a 2-m beam trawl (●) and a 6-m beam trawl (○) in Shijiki Bay. Depth contours shown in meters.

2.　放流種苗の追跡

1985年は放流種苗の追跡調査を放流6時間後から5月28日までの毎日実施した．一方，1986年には放流6時間後から 5月30日までの 毎日， 6月には 約1週間間隔，それ以降は9月23日まで約1ケ月間隔で実施した．放流種苗の再捕には，渚域では桁網（網口幅2 m，高さ 30cm， 網の 長さ 4 m， コッドエンドの目合い3 mm）[3] を，沖合砂底域では従来の底びき網（張竹長6 m，コッドエンドの目合い3 mm）[11] にヒラメおこし用チェーンを装着した網を使用した．曳網方法は，桁網においては0.3〜0.4 m・s^{-1} の人力びきとし，底びき網では約2ノット5分間の漁船びきとした．桁網調査では大志々伎，潮見鼻，肥，田の浦，船越，向月，飯田浦の各渚域に海岸線と平行に1〜4定線を設け曳網を行い，底びき網調査においては湾内砂底域に10定線を設け曳網を行った（Fig. 1）．1986年には放流点のG-2 の周囲に さらに8定線（湾口側および 湾奥側に各4定線）を設け，底びき網調査を実施した．これらの曳網調査に加えて，放流種苗の移動傾向を知る目的で，放流点の周囲で刺網（11〜13節目）調査を，藻場の魚食性魚類による放流種苗の捕食状況を把握する目的で，船びき網調査を実施した．また，放流直後のヒラメ種苗の行動の潜水観察，潜水枠どり法による個体数推定も 適宜実施した． なお， 桁網および 底びき網による ヒラメの 採集時には， NUS ネット （目合い 0.5mm）[12] による餌料生物採集を併せて実施した．

3.　再捕種苗の分析

採集した魚類と餌料生物は，それぞれ10%ホルマリン液および5%中性ホルマリン液で固定・保存した．再捕後 直ちに 船上で選別・固定した ヒラメ 人工種苗は，尾数・全長・体長・体重・白化の程度を測定し，胃内容物重量・組成を調べた．放流種苗の減少率は，放流後の経過日数と対数変換した1曳網当りの平均再捕尾数との間に直線を当てはめることにより算出した．白化の程度は，有眼側の体面積に対する白化面積の割合により，白化部分が全く無い個体をN型，白化面積の割合が0%より多く50%以下の個体をI型，白化面積の割合が50%より多い個体をII型として3段階に分けて示した．さらに，放流ヒラメの被食状況を把握するために，桁網，底びき網，船びき網で採集された魚食性魚類の胃内容物を，天然ヒラメも含めて調べた．

結　　　果

1.　再捕結果

1985年および1986年のヒラメ放流種苗の合計再捕尾数はそれぞれ577尾，450尾となり，再捕率は1.56%，1.83%であった（Table 1）．両年ともに，放流点での再捕がそのほとんどを占め（放流点での再捕尾数／全再捕尾数：1985年—97.4%， 1986年—99.6%）， 放流点以外での再捕尾数は，渚域ではそれぞれ15尾（0.38尾／曳網） および2尾（0.05尾／曳網）， 沖合砂底域では全く再捕されなかった．また，再捕期間については，1985年では放流33日後に放流点の田の浦で最終再捕があり，他の渚域（飯田浦と肥）でも32日後まで再捕が可能であった．一方，1986年には最高28日後に渚

Table 1. 志々伎湾におけるヒラメ人工種苗の放流および再捕状況
Characteristics of flounder released in Shijiki Bay and the total number of fish recaptured.

Date of release	No. fish released	Total length (Mean±SD; mm)	Release station	Recapture station	No. fish recaptured	Last catch (days)
24 Apr. 1985	37,000	33.7±8.35	Tanoura	Tanoura	562	33
				Beach sta.	15	32
				Subtidal sta.	0	—
				Total	577	
20 May 1986	24,600	81.2±12.80	G-2	G-2	448	8
				Subtidal sta.	0	—
				Beach sta.	2	28
				Total	450	

域の田の浦で再捕されたが，放流点の G-2 での最終再捕は放流8日後にすぎなかった（Table 1）．

放流種苗の移動傾向は，放流場所以外での再捕尾数が極端に少ないため明確ではない．1985年の場合は，放流点の田の浦以外では，飯田浦で放流16日後に初めて放流点での再捕尾数を超える放流種苗が再捕された．1曳網当りの再捕尾数は放流16日後に飯田浦で1.3尾（田の浦：0.3尾），24日後には船越で0.5尾（田の浦：0尾），26日後には飯田浦で2.0尾（田の浦：0尾），そして放流32日後の最後の再捕は飯田浦および肥で1尾ずつ採集されている（田の浦：0.3尾）．この再捕結果を，肥より北側の渚である潮見鼻，大志々伎および沖合砂底域での再捕が皆無であったことと考え合わせると，放流種苗の陸岸に沿った時計回りの移動傾向がうかがわれる（Fig.1 参照）．一方，1986年の放流点以外での再捕は，放流16日後の船越および28日後の田の浦の渚における2尾のみであった．しかし，放流点G-2の周囲に設けた湾口側および湾奥側の各4定線における底びき網による1曳網当りの再捕尾数は，放流6時間後にはそれぞれ，2.0，7.5尾，1日後には10.3，20.3尾，2日後には16.0，15.8尾，3日後では4.3，15.3尾，4日後には2.0，12.5尾，8日後には0.3，0.3尾となり，湾奥側で多くの放流種苗が再捕されたことを示している．従って1986年の場合，放流点から湾奥側の浅所に向かう放流種苗の移動が想定される．

2. 放流種苗の減少傾向

放流種苗の再捕尾数は経日的に減少し，両年とも，放流後の経過日数（t）と1曳網当り（1985年は桁網，1986年は底びき網）の平均再捕尾数（N）の間には，分散分析の結果，次式に示す直線の当てはめが有意であった（Fig. 2，点線）．

1985年：$\ln N = 2.211 - 0.193t$ （$P<0.01$）　(1)

1986年：$\ln N = 3.883 - 0.599t$ （$P<0.01$）　(2)

上式から1日当りの生残率（S）を推定すると，

1985年：$S = e^{-0.193} = 0.824$　(3)

1986年：$S = e^{-0.599} = 0.549$　(4)

となる．従って，減少率（$1-S$）は1985年が17.6%／日，1986年が45.1%／日と計算され，1986年の放流種苗の減少が1985年に比べて高かった．次に，放流種苗の全長（TL）による減少傾向の違いを知るために，両年のヒラメを全長35㎜および75㎜を境にそれぞれ2群に分け，経過日数と平均再捕尾数の関係をみた．この全長の境界値は，両年における2群の放流後1日目の再捕尾数が同程度となるよう選んである．その結果，次式に示す直線の当てはめが有意であった（Fig. 2，実線）．

1985年

$TL < 35$㎜：$\ln N = 2.618 - 0.622t$ （$P<0.01$）(5)

$TL \geqq 35$㎜：$\ln N = 1.526 - 0.143t$ （$P<0.05$）(6)

1986年

$TL < 75$㎜：$\ln N = 2.530 - 0.500t$ （$P<0.05$）(7)

$TL \geqq 75$㎜：$\ln N = 3.595 - 0.657t$ （$P<0.01$）(8)

ただし，両群の直線の傾きには，1985年には有意差が存在したが（$P<0.05$），1986年には存在しなかった．この結果から，1985年の減少率は全長35㎜未満の個体では46.3%／日，35㎜以上では13.4%／日と計算され，小型種苗の減少率が極めて高かった．一方，1986年の放流種苗は，全長75㎜未満の個体で39.4%／日，

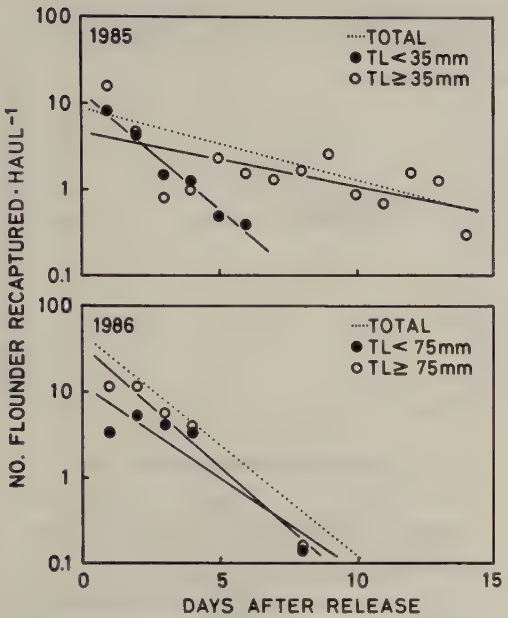


Fig. 2. 放流ヒラメの再捕尾数の経日変化．1985年は桁網，1986年は底びき網による採集結果を示す
Changes in number of flounder recaptured with a 2-m beam trawl in 1985 and with a 6-m beam trawl in 1986.

75mm以上で48.2%／日の減少率を示したものの，前述のごとく両種苗間で有意差はない．ここでは，再捕期間中の種苗の成長による全長35および75mmの境を超えた，小型群から大型群への移行を考慮していない．ただ，両年とも再捕期間が短いこと（1985年の全長35mm未満の小型群では放流後6日間，1986年は8日間），また，1985年は摂餌不良（後述）を反映して放流種苗がほとんど成長しなかったと想定されるため[13]（1985年の放流点である田の浦では天然ヒラメの成長速度も0.4mm/日と悪い*），再捕期間中の成長の影響は無視できる．

種苗生産したヒラメに見られる白化個体は，その目立ち易さのために捕食を被り易いことが予想される．そこで，ヒラメ再捕個体中に占める白化個体割合の経日変化を追った（Fig. 3）．1985年には白化個体の割合は放流後短期間で減少し，14日後には0となった．しかも，白化の程度が進んだ個体ほど速やかに減少した．また，この減少傾向は特に小型個体において顕著であり，全長35mm未満の個体では，放流5日後には白化個体は全く再捕されなくなった．従って，全長35mm未満の個体での減少率の高さ（Fig. 2）を考え合わせ

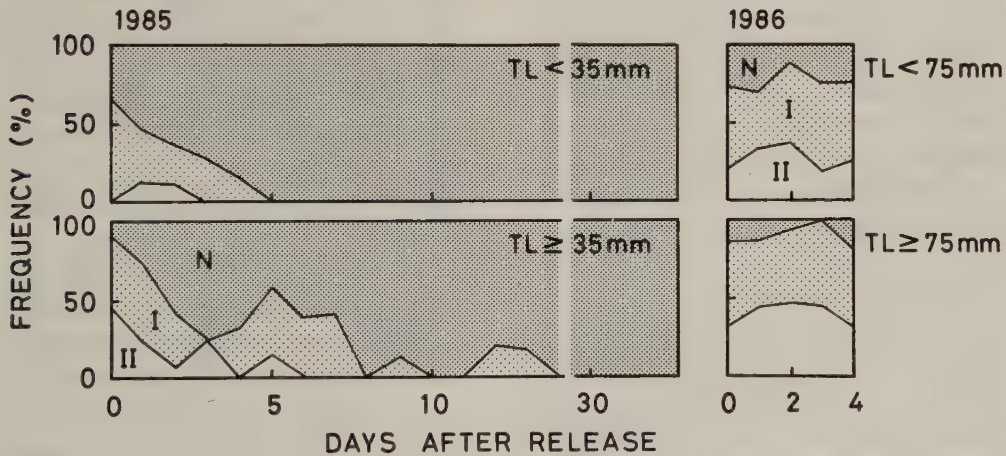


Fig. 3. 再捕したヒラメの白化個体割合の経日変化．N：白化部分の無い個体；I：白化部分の面積が全体の体面積の50%以下の個体；II：白化部分の面積が50%より広い個体
Changes in percent frequency of occurrence of albinic flounder recaptured. N: fish with no albinic area; I: fish with the small albinic area (≦50% of body surface); II: fish with the large albinic area (>50%).

*田中ら（未発表）

Table 2. 再捕したヒラメの空胃個体割合(%)の経日変化．胃内容物調査個体数が５尾以上の日の結果のみを示した
Changes in percent frequency of occurrence of recaptured flounder with a empty stomach.

Year	Total length (mm)	Days after release													
		0.3	1	2	3	4	5	6	7	9	10	12	18	19	27
1985	20.1～40.0	80.0	96.7	100.0	71.4	81.3	80.0	25.0	100.0	40.0	33.3	72.7	27.3	16.7	0
	40.1～60.0	80.0	100.0	100.0	100.0	100.0	87.5	83.3	100.0	75.0	66.7	71.4	100.0	100.0	0
	Total	80.0	98.0	100.0	81.8	85.7	85.7	60.0	100.0	55.6	50.0	72.2	33.3	28.6	0
1986	40.1～ 60.0	—	42.9	42.9	40.0	33.3									
	60.1～ 80.0	80.0	72.3	75.9	30.8	30.3									
	80.1～100.0	100.0	72.4	74.6	42.9	58.8									
	100.1～120.0	100.0	100.0	66.7	60.0	50.0									
	Total	89.5	72.7	73.2	37.2	39.7									

ると，35mm未満でしかも白化の個体の減少率は著しく高い計算となる．一方，1986年は追跡期間は４日間と短いものの，白化個体の割合は全長75mm未満の個体でも75mm以上でもほとんど変化していない．この1986年の結果は，1985年の放流後４日間の結果と比較しても，明らかに異なっている．

3. 放流種苗の摂餌状態および被食状況

放流直後のヒラメ人工種苗には両年とも空胃個体が目立つが，その後の摂餌状態の良否には違いが見られる（Table 2)．1985年には放流後12日目まで空胃個体の割合（空胃率）が70%台と極めて高く，30%台に低下するのに18日を要した．しかし，1986年では放流３日後には空胃率が30%台に低下しており，1985年に比べて放流後極めて短期間の内に摂餌状態が好転した．また，同一年内で比較すると，小型個体ほど短期間で空胃率が低下する傾向が両年ともに見られた（Table 2)．

胃内容物組成についても両年で違いが見られる(Fig. 4)．1985年にはヒラメ幼稚魚の最重要餌料であるアミ目のほかカラヌス目やヨコエビ亜目の摂食割合も高いのに対し，1986年では放流直後からアミ目の摂食割合が圧倒的に高かった．なお，放流種苗の胃内容物中に出現した魚類のうち，1985年には天然ヒラメが２尾（全魚類数の40.0%)，1986年には天然マダイが37尾（77.1%）含まれていた（Fig. 5)．1985年の例は放流１日および27日後に放流場所の田の浦で見られ，全長36.5，37.0mmの放流ヒラメ１尾ずつがそれぞれ13.5，15.0mmの天然ヒラメを捕食していた．一方，

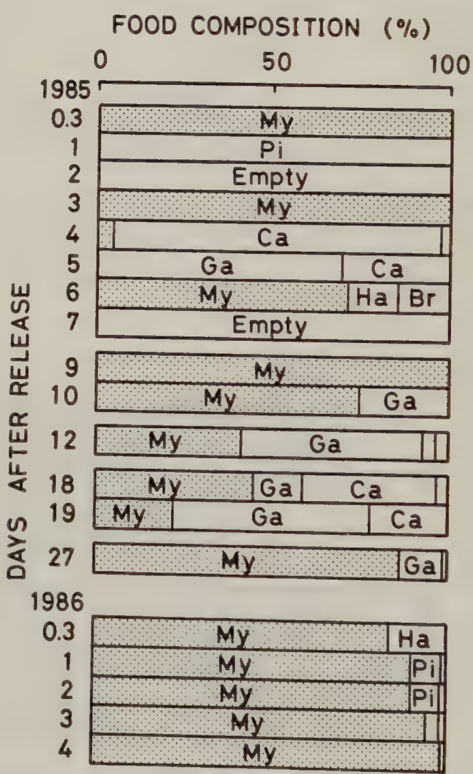


Fig. 4. 再捕したヒラメの胃内容物組成の経日変化（個体数%)．胃内容物調査個体数が５尾以上の日の結果のみを示した．My：アミ類；Ga：ヨコエビ類；Ca：ワレカラ類；Ha：ハルパクチクス類；Br：カニ類；Pi：魚類
Changes in food composition (% by number) of stomach contents of flounder recaptured. My: Mysidacea; Ga: Gammaridea; Ca: Caprellidea Ha: Harpacticoida; Br: Brachyura; Pi: Pisces.

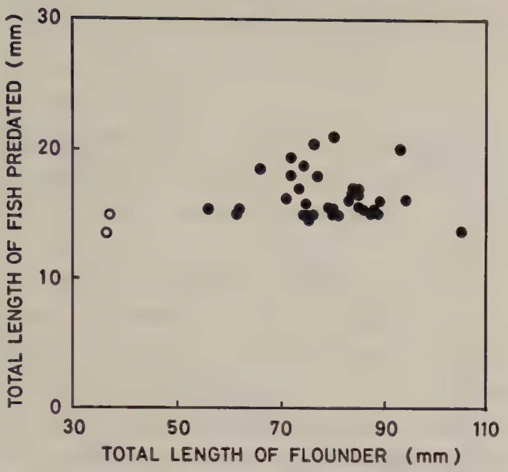


Fig. 5. 放流したヒラメに捕食された天然ヒラメ稚魚（○）および天然マダイ稚魚（●）の全長
Total lengths of juveniles of wild flounder (○) and wild red sea bream (●) predated by released flounder.

1986年の場合は，放流1～4日後に放流場所の G-2 で，32尾の放流ヒラメ（平均全長±標準偏差：79.6±10.10mm）が，それぞれ1～3尾の着底直後のマダイ稚魚計37尾（16.4±1.81mm）を捕食しているのが見つかった.

ヒラメ放流種苗の被食例は，両年を通じてわずか1例発見されたにすぎなかった．すなわち，1985年の放流1日後に放流場所の田の浦で，放流したヒラメ3尾が天然ヒラメ1尾に捕食されているのが見つかった．捕食ヒラメは全長186.9mmの1歳魚で，被食ヒラメの全長はそれぞれ，31.5，38.4，43.5mmであった．また，被食ヒラメは全て白化個体で，それも白化の程度が最も高いII型の種苗であった.

考　察

志々伎湾におけるヒラメ放流種苗の減少率は，他の海域における報告例[1),*]に比較すると，おおむね高い．一般に，放流種苗の減耗には，大きく2つの要因が考えられる．漁獲，飢餓，被食，活力低下による死亡と，調査水域からの逸散とである．このうち，両年のヒラメ種苗の放流では，追跡調査による再捕率が2%以下であり，かつ湾内でのひき網漁業が禁止されていることから，漁獲死亡は無視できる．また，放流直後の種苗の状態や良好な潜砂状況——放流3時間後には一見してその存在を確認できなくなった——から判断して，活力低下による死亡は考えにくい．従って，ここでは，減耗要因を飢餓および被食による死亡と，逸散に限定して考察する．しかし，これら3つの要因も全く独立な関係にあるわけではない．例えば，飢餓は，餓死だけではなく異常行動や逃避能力の低下に伴う被食機会の増大につながるし，空腹に伴う逸散促進効果を持つことも想定されるからである．この要因間の関係が，減耗要因の特定をさらに難しくさせることになる.

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志々伎湾における両年のヒラメ放流種苗の追跡調査結果は以下のようにまとめられる．1985年：①小型個体の減少率が大型個体に比べて著しく高い（Fig. 2)；②白化個体の割合は放流後急激に減少し，しかも，それは小型個体において著しい（Fig. 3)；③摂餌状態は環境中の餌料条件——放流場所の田の浦では最重要餌料であるアミ類の分布密度が低い[14)]——を反映して不良であるが，小型個体は大型個体に比してより短期間で好転する（Table 2)．1986年：①1985年に比べると減少率は高いものの，小型個体と大型個体の間で差は見られない（Fig. 2)；②白化個体の割合は小型個体でも大型個体でも放流後ほとんど変化していない（Fig. 3)；③摂餌状態は環境中の餌料条件——放流場所のG-2 ではアミ類の分布密度が高い[14)]——を反映して良好であるが，小型個体のほうがさらに良好である（Table 2).

この両年の結果を比較してヒラメ放流種苗の減耗要因を推定すると，1985年では被食がその主要因となった可能性が高い．一般に底魚類の体長と水深の間には正の相関が見られることから[15)]，志々伎湾湾奥部のような浅海域では被食魚種の体長が大きくなるにつれて

その捕食(可能)者数が極端に減少すると考えられる．同時に，捕食者からの逃避能力（発見された後の遊泳力）は小型個体ほど低いため捕獲が容易であることを考慮すると，1985年の小型個体の急激な減少は被食の結果であると判断できる．さらに，白化個体の急激な減少は，白化個体が捕食者に発見され易いこと――たとえ潜砂状態が良好でも移動や摂餌の際にはやはり目立つ――を考えると，この判断を支持している．もっとも放流種苗の摂餌状態の不良さは，飢餓の影響も無視できないことを示唆している．しかし，小型個体における相対的な摂餌状態の良好さとその急激な減少との矛盾，全長30㎜前後のヒラメの飢餓耐性の高さ――体長17.3㎜のヒラメの50%餓死日数は約17日であり，しかも，飢餓耐性は成長とともに著しく増大する[16)]――を考慮すると餓死の可能性は低い．また，放流場所の田の浦以外の渚域での再捕例は逸散の可能性を示唆するが，その再捕尾数が少ないこと，四方を藻場や岩礁に囲まれた半閉鎖的な田の浦の環境を考えると主要因になったとは思われない．従って，小型でしかも白化個体の多かった1985年のヒラメ放流種苗の減耗は，被食が主要因であったと考えるのが妥当であろう．そして，おそらくは，餌不足による飢餓が，被食機会の増大と成長遅滞のための被食危険期間の長期化を招く結果となったのであろう．ただし，ヒラメ放流種苗の被食例は3尾発見されただけであった．しかし，これは魚類のみによる結果であり，特にヒラメ稚魚の捕食者として重要であることが報告されているエビジャコ*,**等の無脊椎動物の捕食圧を考慮にいれると，被食事例は増えていたかもしれない．これに対し，1986年は放流場所以外での再捕例はわずかに2尾であったが，逸散が減耗の主要因となった可能性が高い．平均全長81.2㎜の大型種苗を放流したこと，小型個体と大型個体の減少率に差がなかったこと，さらには，放流後の白化個体の割合が減少していないことから，被食が減耗の主要因になったとは考え難い．同様に，放流後の摂餌状態の良好さは飢餓の可能性を否定する．従って，残る逸散が1986年の減耗要因と考えざるを得ない．実際，放流点G-2の周囲での底びき網による再捕結果は，放流種苗の湾奥側に向かう移動傾向を示していた．しかし，餌料条件も良く，しかも被食も考えられない放流場所からなぜ急速に逸散したかは不明である．遊泳力の優れた大型種苗にとって，湾奥部砂底域という田の浦に比べるとより開放的で広い砂底という環境が，結果的には逸散を促進することになったものと推察される．

以上のヒラメ人工種苗の減耗要因の検討結果から，種苗の体サイズ，白化個体割合，餌料環境が放流後の生残率向上のための重要なポイントとなることは容易に理解できる．一方，ヒラメ種苗の放流の際に注意を要するもう一つの重要な側面は，本種が成長とともにその食性を魚食性に転換するため，放流種苗が他の生物，特に漁業上の有用魚種を捕食する危険性を持っている点である．実際，1985年の放流では，放流種苗による天然ヒラメの捕食例が2例見つかった（Fig. 5）．このようなヒラメの共喰い現象は複数の海域から報告例があり[5,17)]，志々伎湾でも天然魚については1尾当り最高16尾の着底直後の稚魚が捕食された例が報告されていた[4)]．ヒラメ種苗の放流場所には天然ヒラメ稚魚の好適な生息場所が選定される場合が圧倒的に多いため，その放流時期・体サイズによっては天然稚魚が大量に捕食される恐れは十分に考えられることである．一方，1986年には，32尾のヒラメ放流種苗が着底直後のマダイ稚魚を計37尾捕食していた（Fig. 5）．放流ヒラメによる天然マダイの捕食例は他にほとんど報告がなく，天然ヒラメによる捕食例も，志々伎湾においては，両者の出現時期・場所および体サイズの違いにより見つかっていない（山口県油谷湾では天然・人工両ヒラメによる捕食が報告されている*）．しかし，種苗生産時期の違いや加温飼育などにより放流時の体サイズが比較的自由に選択できる人工種苗の放流では，その放流時期・場所・体サイズによっては天然マダイ稚魚が捕食される可能性も十分生じてくる．これは他の有用魚種にとっても同様である．現時点での海産魚の種苗放流においては，その放流効果のみに注目しがちである．しかし，ヒラメ放流種苗のように他の漁業上の有用種の生残に直接影響を及ぼすことが危

*山下　洋・長洞幸夫・山田秀秋　1991：飼育実験により推定したエビジャコのヒラメ着底稚魚捕食能力．平成3年度日本水産学会秋季大会講演要旨集，37.

**青海忠久・木下　泉・田中　克・斉藤知巳　1991：凄惨！ヒラメ稚魚とエビジャコの食う一食われる関係．平成3年度日本水産学会秋季大会講演要旨集，189.

*土門　隆・木下貴裕・小嶋喜久雄・花渕靖子　1987：底生魚類の複合放流技術の開発．マリーンランチング計画昭和61年度研究報告，130-131.

惧される場合には，特に，その影響をも考慮に入れた放流計画の立案が必要となってくるだろう．

文　献

1) 富永　修　1991：ヒラメを例とした標識放流実験結果について．北水研技報，(2)，27-30．

2) M. Tanaka, T. Goto, M. Tomiyama, H. Sudo and M. Azuma 1989: Lunar-phased immigration and settlement of metamorphosing Japanese flounder larvae into the nearshore nursery ground. *Rapp. P.-v. Réun. Cons. int. Explor. Mer*, **191**, 303-310.

3) 後藤常夫・首藤宏幸・冨山実・田中克　1989：志々伎湾におけるヒラメ稚仔魚の着底時期．日水誌，**55**，9-16．

4) 藤井徹生・首藤宏幸・畔田正格・田中克　1989：志々伎湾におけるヒラメ稚仔魚の着底過程．日水誌，**55**，17-23．

5) M. Tanaka, T. Goto, M. Tomiyama and H. Sudo 1989: Immigration, settlement and mortality of flounder (*Paralichthys olivaceus*) larvae and juveniles in a nursery ground, Shijiki Bay, Japan. *Neth. J. Sea Res.*, **24**, 57-67.

6) 首藤宏幸　1985：志々伎湾におけるヒラメ幼稚魚の摂餌特性．魚類研究会報（西海区ブロック浅海開発会議），(3)，39-43．

7) 首藤宏幸・畔田正格・池本麗子 1985：志々伎湾におけるヒラメ幼稚魚の分布と食性．マリーンランチング計画（ヒラメ・カレイ）プログレスレポート，(1)，25-30．

8) 首藤宏幸・鬼頭　鈞・畔田正格・池本麗子　1985：志々伎湾におけるヒラメ幼稚魚生息場所の底環境．マリーンランチング計画（ヒラメ・カレイ）プログレスレポート，(1)，77-80．

9) 東　幹夫・陣野聡子　1980：平戸島志々伎湾の底生動物群集—I．マクロベントスと堆積物による生息場所分析の試み．西水研研報，(54)，195-208．

10) 首藤宏幸・池本麗子・畔田正格　1983：志々伎湾における若魚期マダイの生息場所の評価．西水研研報，(59)，71-84．

11) 畔田正格・池本麗子・東　幹夫　1980：志々伎湾における底生生活期マダイ当歳魚の分布と成長．西水研研報，(54)，259-278．

12) 東　幹夫　1983：NUSネットの使用法と採集効率の推定．魚類研究会報（西海区ブロック浅海開発会議），(1)，93-101．

13) 池本麗子・首藤宏幸・加藤史彦　1986：志々伎湾におけるヒラメ天然稚魚と放流種苗の生態．マリーンランチング計画（ヒラメ・カレイ）プログレスレポート，(2)，23-35．

14) 東　幹夫・橋村浩一・六倉静香　1985：志々伎湾におけるアミ類の日周的垂直移動．魚類研究会報（西海区ブロック浅海開発会議），(3)，53-59．

15) 岸田周三・堀川博史・通山正弘　1989：土佐湾における底魚類の成長に伴う生息水深の変化．西日本底魚部会報（漁業資源研究会議），(7)，43-52．

16) 田中　克　1988：志々伎湾におけるヒラメ稚仔魚の着底減耗について．マリーンランチング計画（ヒラメ・カレイ）プログレスレポート，(3)，1-16．

17) 南　卓志　1986：日本産カレイ目魚類幼稚仔魚の被食事例．日水研研報，(36)，39-47．

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Preliminary Observation of Swimming and Feeding Behaviours for the Wild Early Juvenile Red Sea Bream, *Pagrus major*, in Relation to Copepod Swarm

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ABSTRACT

SCUBA diving observation was made at 4 sites with the depth of sea bottom of 7 to 14 m in the coastal area, western Kyushu, May–June, 1990. The early juveniles of *Pagrus* were swimming keeping a distance of 3 to 5 cm and sometimes about 10 cm above the sea bottom without attaching to the bottom even for a moment. They swam vigorously without intermission at sites where copepod swarm was not present and their path was usually straight. The distance of a single dart ranged from 30 to 50 cm. On the other hand, they tended to stay still at a certain position at sites where the swarm developed. A *Pagrus* juvenile was moving its lips continuously at the edge of a copepod swarm in a hollow of a diameter about 20 cm on the sea bottom. The results of stomach contents survey for 5 individuals (13 to 17 mm in fork length) caught suggested that food habit of early juvenile *Pagrus* depended on the food conditions of their habitat.

INTRODUCTION

The red sea bream *Pagrus major* (Temminck et Schlegel), "Madai" in Japanese, is one of the most important commercial fishes in Japan, and systematic enhancement techniques of natural population in field has been demanded. For the early juvenile *Pagrus* as well as other ground fishes, food problem is of particular importance to survive. During this early period, they may be put under certain severe physiological and ecological conditions due not only to morphological change but also to environmental change because of ontogenetic downward migration to the sea bottom.

The stomach of the early juvenile *Pagrus* (13 to 35 mm in fork length) is often

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filled almost exclusively with copepods *Acartia steueri* and *A. omorii.*[1] The copepods sometimes make aggregation in certain spatial shape and size, so called swarm, which varies according to the bottom topography, namely, the presence of stone, rock, and sometimes macrophyte.[2,3] A tentative estimation of food requirement of the early juvenile suggested that they may not be able to maintain their metabolism and growth without the prey organisms present in swarming.[4]

This paper describes the result of preliminary observations with SCUBA to elucidate the relationship between the presence of copepod swarm and the behaviour of natural population of *Pagrus major* in its early demersal life.

METHOD AND MATERIALS

Underwater observations by SCUBA dives were made at 4 sites with sea bottom depth of 7 to 14 meters in the coastal area of Nagasaki Peninsula, western Kyushu, during May and June. 1990 (Fig. 1). To unveil swimming and feeding behaviour in situ, one of the authors (YM) and a professional SCUBA diver crept along the sea bottom during day to make sure with naked eyes of the presence of the red sea bream juveniles. Eleven dives were made (Table 1), for a total of



Fig. 1. Location of SCUBA diving sites in the vicinity of Nagasaki Peninsula, May-June, 1990.

Table 1. Record of SCUBA observations for *Pagrus major* juvenile and environmental conditions in the vicinity of Nagasaki Peninsula, western Kyushu, May–June, 1990.

Date	Site no.	*Pagrus* observed Nos.	*TL(mm)	*Pagrus* caught Nos.	FL(mm)	Specimen no.	Copepod swarming	Depth of sea(m)	Bottom material	Current (cm/sec.)	Search time(min.)
May 23	3	23	15–25	2	13.0	01	Absent	11–14	Sand	3.1–3.3	186
					17.0	02					
May 31	1	4	15–20	1	13.6	03	Present	9–13	Muddy sand	0.7–0.8	235
June 6	4	0					Present	10–12	Sand, boulder	–	77
	3	7	15–25	1	14.2	04	Absent	12–13	Sand	ca. 2	93
June 12	2	0					Present	8–11	Sand	–	31
	1	2	12,15				Present	10	Muddy sand	ca. 1	56
	2	0					Present	7–9	Sand	–	80
	1	4	15–40	1	14.4	05	Present	9	Muddy sand	–	86
Total		40		5							844

*Approximate total length of *Pagrus* by naked eye observation
FL refer to as fork length

844 man minutes excluding the time of descent and ascent. A spoon net of 30 cm mouth diameter, was once used to dip the juveniles, but the dipping usually kept them away from the mouth of the net. A hand made plankton net of rectangular mouth (20 cm in height, 50 cm in width) with wings of coarse knettings (100 cm long) for gathering the fish was somewhat effective. The size of mesh aperture was 0.33 mm in both gears.

The swarming zooplankters were collected with Plastic Suction Sampler developed by KIMOTO et al.[3] Fish and zooplankton were preserved in 10% formalin solution. Stomach contents of the juveniles were sorted to the taxonomic group. The number of individuals contained in each stomach was counted under microscope. The dry weight of each item was determined.

Velocity of the bottom water current was determined by the time taken for piece of seaweed to flow on the graduated 1 meter long rope set on the sea bottom.

RESULTS AND DISCUSSION

Forty individuals of the red sea bream juveniles were found. They were solitary without exceptions. They were identified *Pagrus major* for the collected specimens to be mentioned below by an ichthyologist of our Institute. Dr. M. MATSUOKA to whom we are deeply indebted. *Pagrus* appeared at Sites 1 and 3 with rather flat sandy bottom. The bottom of Site 1 was rather muddy. None were observed at Site 2 of sandy bottom. Neither was at Site 4 of sandy bottom on which 20 to 40 cm diameter round rocks were scattered. Approximate length of the body (total length, TL) ranged from 12 mm to 40 mm by naked eye observation. The individuals with relatively small body size were similar to that obtained by TANAKA[5] by beam trawl on the sandy bottom of Shijiki Bay, Kyushu. MIMURA et al.[6] observed the rapid disappearance of *Pagrus* larvae with 6 to 10 mm TL from the surface layer, and numerical increase of the early juveniles with 14 to 17 mm TL at the bottom layer of a big saline pond. These larvae hatched from the artificially fertilized eggs, and fed on the natural zooplankton of the pond, thus without any artificial food. The smaller individuals of the present observation, therefore, may be regarded as those caught immediately after settling.

The juveniles were swimming keeping a distance of 3 to 5 cm or sometimes about 10 cm above the sea bottom without attaching to the bottom for ever a moment. They swam vigorously without intermission at Site 3. The path of their swimming was usually straight and the distance of a single dart ranged from 30 to 50 cm. On the other hand, at Site 1, they seemed rather gentle and tended to stay at a special spot above concaved bottom. A *Pagrus* of 15 mm TL kept a position 5 to 6 cm above the bottom at the center part of a hollow of diameter about 20 cm

where copepod swarm developed. It faced the flow of a speed less than 1 cm/sec, and changed the direction of its head as soon as the direction of the flow changed. It was stemming the flow moving its lips continuously in the hollow. We watched its mouth carefully, but we could not discriminate whether it was biting or breathing. Such apparatus as submersible magnifying scope would be desirable for detailed observation. Standing with the ventral fins on the top of the macrophyte body or ousting of other individuals usually performed by the artificial seeds,[7] were not observed.

Copepod swarms were abundantly distributed all over just above the sea bottom at Sites 1 and 2, and sporadically or almost absent at Sites 3 and 4. The planktors in the swarm were mainly composed of juvenile and adult of *Acartia omorii* and *Oithona* sp. The numerical composition of species somewhat varied according to day and position investigated even at the same site (Table 2).

Table 2. Numerical composition of swarming zooplankton collected with the Plastic Suction Sampler at Site 1, Nagasaki Peninsula, May-June, 1990 (Organisms per 1 liter of sea water)

Sample no.	03	04	08	09
Sampling date	May 31	May 31	June 12	June 12
Copepods				
Pseudodiaptomus sp.		1		
Acartia omorii adult		1	237	28
Acartia omorii juvenile	40	4	423	49
Oithona sp.	57	8	33	105
Harpacticoids		1		
Nauplii	3	7		
Mysids		1	16	
Total	100	23	709	182

Pagrus was rather abundant at the site where zooplankters in swarm were less abundant and vice versa. This means that abundant zooplankters in swarm does not always induce the larval *Pagrus* to settle to the bottom.

We obtained 5 individuals of *Pagrus* juveniles; 3 at Site 3 and 2 at Site 1. The fork length of them ranged from 13 mm to 17 mm. The microscopic examination of the stomach contents showed that *Pagrus* feed pelagic copepods at Site 1 and benthic animals at Site 3 (Table 3). Among pelagic copepodas at Site 1, major members were *Oithona* sp. in number and adult forms of *Acartia* in weight. In contrast, benthic harpacticoid copepods and gammarid amphipods were important forage at Site 3. This suggests that the juveniles vary flexibly their food according to circumstances,[6] depending on swarming copepods at swarm rich area and on benthic

Table 3. Stomach contents of *Pagrus* juveniles caught at 2 sites of Nagasaki Peninsula, May–June, 1990

Specimen no.	01		02		03		04		05	
Sampling date	May 23		May 23		May 31		June 6		June 12	
Sampling site no.	3		3		1		3		1	
Fork length of *Pagrus* (mm)	13.0		17.0		13.6		14.2		14.4	
Body wet weight (mg)	27		80		33		34		43	
	Nos.	Dry wt. (μg)	Nos.	Dry wt. (μg)	Nos.	Dry wt. (μg)	Nos.	Dry wt. (μg)	Nos.	Dry wt. (μg)
Calanoid copepods										
Acartia adult					6	58.8*			3	29.4*
Acartia juvenile	1	0.3*								
Cyclopoid copepods										
Oithona					80	29.6*			149	55.1*
Harpacticoid copepods	32	384*	91	1084	1	?	26	312*	3	36*
Mysid					1	28				
Gammarid amphipods			7	1940	3	104				
Caprelline amphipod	1	?								
Bivalve	1	207								
Unidentified			1	469						
Total	35	591.3+	99	3493	91	220.4+	26	312	155	120.5
Stomach content weight/ **body weight (%)		10.9+		21.8		3.3+		4.6		1.4

*Calculated from UYE's formulae[8].

**Assumed that dry weight of juvenile *Pagrus* is 20% wet weight

animals at zooplankton poor area. Particular attention must be paid to the fact that the volume of stomach contents of *Pagrus* at zooplankton poor area excelled that of the zooplankton rich area (Table 3). More cases of observations are needed for further knowledge on the feeding behaviour and food problem for the early juvenile *Pagrus* in natural environment.

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REFERENCES

1) M. Tanaka, H. Ueda and M. Azeta 1987 : Near-bottom copepod aggregations around the nursery ground of the juvenile red sea bream in Shijiki Bay. *Nippon Suisan Gakkaishi*, **53** (9), 1537-1544.

2) H. Ueda, A. Kuwahara, M. Tanaka and M. Azeta 1983 : Underwater observations on copepod swarms in temperate and subtropical waters. *Mar. Ecol. Prog. Ser.*, **11**, 165-171.

3) K. Kimoto, J. Nakashima and Y. Morioka 1988 : Direct observations of copepod swarm in a small inlet of Kyushu, Japan. *Bull. Seikai Reg. Fish. Res. Lab.*, (66), 41-58.

4) M. Tanaka, H. Ueda, M. Azeta and H. Sudo 1987 : Significance of near-bottom copepod aggregations as food resources for the juvenile red sea bream in Shijiki Bay. *Nippon Suisan Gakkaishi*, **53**(9), 1545-1552.

5) M. Tanaka 1985 : Factors affecting the inshore migration of pelagic larval and demersal juvenile red sea bream *Pagrus major* to a nursery ground. *Tranact. Amer. Fish. Soc.*, **114**, 471-477.

6) G. Mimura, S. Yoshimoto, S. Saito, T. Hayashi and M. Takahashi 1984 : On ecological observations of the larval red sea bream in the extensive farming saline pond. *J. Fac. Appl. Biol. Sci., Hiroshima Univ.*, **23**, 95-119. (in Japanese with English summary)

7) A. Ohno, S. Hidaka and A. Takechi 1983 : [Feeding of larval red sea bream in the extensive saline pond.] *Kyoukai Kenkyu Shiryo*, (24), 38-65, Nippon Saibai-Gyogyou Kyoukai, Tokyo. (In Japanese)

8) S. Uye 1982 : Length-weight relationships of important zooplankton from the Inland Sea of Japan. *J. Oceanogr. Soc. Japan*, **38**, 149-158.

着底初期天然マダイの行動のスキューバ予備観察

森 岡 泰 啓・中 嶋 純 子

抄 録

着底初期のマダイの生き残りにとって餌料生物の濃密な局所的分布，すなわちスオームの存在が必須であるという報告があることから，天然マダイ稚魚の遊泳と摂餌行動が主要餌料であるかいあし類のスオームとどのように関わっているかを海洋現場において研究するための予備的調査として潜水調査を行った．1990年5月23日から6月12日までの4カ日の昼間に長崎半島西岸の水深10mを中心とする4地点において著者の1名と専門のダイバー1名が延べ14時間のスキューバ潜水を行い，マダイ稚魚を探索した．

都合40尾のマダイ（全長約15—40mm）を視認し，5尾（尾叉長13—17mm）を捕獲することが出来た．マダイは，流れが緩慢であり，かいあし類のスオームがよく発達した場所に少なく，その逆の場所に比較的に多かった．このことはスオームの存在が必ずしもマダイの着底を誘引する因子とは限らないことを示している．

マダイ稚魚の遊泳層は海底上3～5cm，時には10cmであり，魚体が海底に接することはなかった．マダイは，スオームが形成されていない場所では30—50cmを1単位とする直線的で機敏な泳ぎを断続的に繰り返したが，スオームの発達した場所では遊泳活動は緩慢で，ひとつところに停滞しがちであった．あるマダイ（全長15mm程度）が直径約20cm，深さ数cmの窪みの中，海底上5－6cmの場所で口を間断なく開閉しているのを認めた．そこは窪みに形成されたかいあし類スオームの縁辺部の潮下であった．口の開閉が捕食，呼吸のいずれかを確認すべくダイバーがマダイまでの距離約40cmまで接近したとき機敏に逃避され，それはできなかった．

捕獲したマダイの胃内容物は，かいあし類スオームの発達した場所のものがスオーム構成種を捕食していたのに対して，スオームの発達していない場所のものはよこえび類，あみ類，ハルパクチクス亜目かいあし類など底棲甲殻類を主食していた．これらのことはマダイの柔軟な食性を示唆している．

Further Investigation of Zooplankton Biomass Share in the Collections with Plankton Net in the Waters to the West of Kyushu

Junko NAKASHIMA*, Yasuhiro MORIOKA** and Katsunori KIMOTO***

ABSTRACT

This sequel study was carried out to estimate the amount of very zooplankton in a plankton net haul. Vertical hauls with the triplet plankton nets (45 cm in mouth diameter, filtering cloths of 335, 200 and 100 μm mesh aperture each) were made once at a site and three times at another site in the Goto-nada waters off western Kyushu in May 1987. Zooplankters were separated from phytoplankton and carcass of phytoplankton and zooplankton by hand under dissecting microscope.

The component ratios of zooplankton biomass were rather constant among mesh sizes and sampling stations ranging from 83 to 89% of the whole collection. The relative abundance of phytoplankton biomass converted from chlorophyll*a* increased and that of the carcass decreased when the mesh size decreased, occupying 2 to 16% and 2 to 12%, respectively.

INTRODUCTION

Plankton net is commonly used for quantitative research of middle-sized zooplankton. The weight of the whole body of crude sample caught with plankton net per unit volume of sea water is often useful for the primary index of zooplankton biomass in the area and season concerned. However, the net catches not only animal plankters but also phytoplankton, detrital material of carcass of zooplankton and phytoplankton, and sometimes other detritus. Therefore, the "zooplankton biomass" is over estimated if the above mentioned index is used. HIROTA and SZYRER[1] measured C/N ratio for natural population of microzooplankton plus de-

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tritus in a Hawaiian bay, and introduced the microzooplankton biomass in terms of C and N using the previous values of C/N ratio of zooplankton and detritus. This manner seems practical, however, C/N ratio of detritus may be largely variable according to the degree of degeneration of the organisms. MORIOKA et al.[2] showed the relative abundance of zooplankton, phytoplankton and carcasses by hand sorting the samples collected with plankton net of 3 different sizes of mesh from the Goto-nada waters in March 1987. The present paper intends to evaluate the amount of very zooplankton in a whole plankton collection to get the precise biomass of zooplankton assembly collected in May 1987 by the same manner as that of the preceding paper.[2]

MATERIALS AND METHODS

Plankton samples were collected by vertical hauls with the cylindric conical triplet plankton nets, whose mouth rings of 45 cm in diameter each are arranged side by side horizontally and the mesh sizes of filtering cloth of each net are 335, 200 and 100 μm (nytal® 13XX, 7XX and 52GG, respectively). Vertical hauls from the near of the bottom to the surface of the sea were made on board the research vessel *Yoko Maru* (500 gross tons), once at a sampling site and three times at another in the Goto-nada waters to the west of Kyushu in May 1987 (Table 1).

Table 1. An outline of sampling conditions for the triplet plankton net hauling and the amount of phytoplankton in the Goto-nada waters, May 14, 1987.

Stn. no.	Position	Depth of sea (m)	Hour	Swell	Wave	Depth of haul (m)	No. of hauls	*Phytoplankton (mg/m^3)
1	32°45′ N 129°17′ E	123	14 : 32– 15 : 24	4	5	110–0	3	573
2	33°08′ N 129°17′ E	67	08 : 02– 08 : 48	3	5	60–0	1	260

*Mean dry weight (multiplied chlorophyll*a* by 500) for vertical column from the surface to the near of the sea bottom

The samples were divided into two subsamples with a splitting box (KOZASA unpublished) which was originally designed by MOTODA,[3] and four aliquots properly treated for different purposes, as shown in Fig 1, were preserved on board the ship. Calibration of the splitting box had been made using fresh water instead of sea water containing plankters in the workshop of the ship on a relatively calm sea, in order to obtain the precise dividing ratio. The coefficient of variation of the ratio showed 0.9%. Moreover, water samples were collected with Niskin bottle in several layers

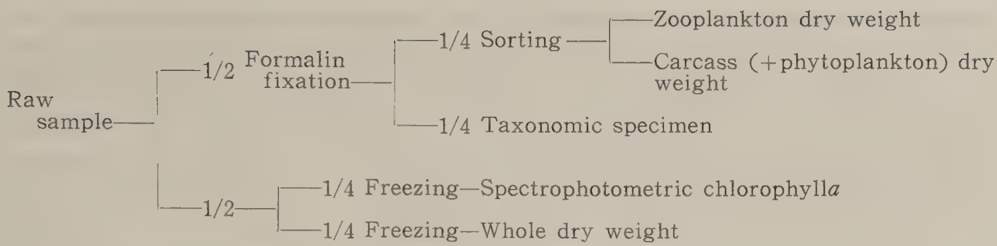


Fig.1 . A diagram showing the process of subsampling and treatment of the aliquots for plankton samples caught by the triplet net haul for evaluating zooplankton biomass share in the collection from the Goto-nada waters, May 1987.

from the surface to the near of bottom at each site for the counting of spectrophotometric chlorophyll*a*.

Zooplankters were removed under dissecting microscope usually from one fourth and sometimes half the volume of the divided sample which had been stored in the formalin sea water solution. It was not always easy for us to distinguish the living animal bodies from non-living ones. The body with substantial content under the armor was deemed living even if the animal failed to have some parts of the body, because it might have been due to some mechanical damage by the plankton net cloth during hauling or rinsing. Animals without body content were classified into the class of "residue", which also included phytoplankters and their corpse, etc.

The sorted zooplankton and residue were rinsed with isotonic ammonium formate to eliminate hindrance salt of their body surface. The same was done for non-sorting samples before freezing. Weight of all materials was measured after heat drying in an electric oven for 24 hours at 60℃. Thus, the values of weight in this paper appear in terms of dry weight.

The dry weight of phytoplankton was estimated from chlorophyll*a* content in it assuming that phytoplankton dry weight/chlorophyll*a* ratio is 500. The amount of phytoplankton taken in the gut of animal is regarded as negligible in the present study. These two assumptions were introduced by Morioka et al.[2] through the discussions on the previous data compiled by themselves.

RESULTS AND DISCUSSION

Weight of the frozen aliquot, the sorted zooplankton and the residue preserved in formalin solution, as well as the calculated phytoplankton are given in Table 2. The whole collection and each item in it usually increased with the decrease of mesh size. The sums of the zooplankton and the residue are not equal to the whole of the non-sorted frozen sample. The former ranged from 46 to 94% of the latter through two stations. This is similar to that observed by Morioka et al.[2] in March

Table 2. Determined dry weight of frozen aliquot, sorted zooplankton and residue from formalin sample, and phytoplankton obtained by vertical hauls with the triplet plankton nets of different mesh sizes at 2 stations in the Goto-nada waters, May 1987.

Stn. no.	Mesh size (μm)	No. of samples	Frozen sample		Formalin fixed sample				*Phytoplankton (mg/m³)	
			Whole material (mg/m³)		Zooplankton (mg/m³)		Residue (mg/m³)			
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	335	3	10.19	0.46	5.91	0.25	1.20	0.21	1.61	1.61
	200	3	14.95	1.14	9.57	1.27	1.17	0.14	0.87	0.14
	100	3	24.85	0.64	12.50	0.55	2.63	0.22	4.47	0.71
2	335	1	26.13	—	10.61	—	1.46	—	0.61	—
	200	1	19.87	—	16.69	—	2.03	—	0.31	—
	100	1	39.17	—	26.62	—	4.04	—	2.15	—

*Spectrophotometric chlorophyll*a* multiplied by 500

of the same year. This is likely due to the decrease of volume and weight of plankters during preservation in formalin solution. The years spent for preservation and sorting process are enough to introduce the decrease of the weight of the organic bodies.[4] The splitting of the samples under rolling condition of the ship may also have caused the disagreement between the weights of the aliquots. i. e. the frozen and the two formalin preserred aliquots. Assuming that the sum of the formalin

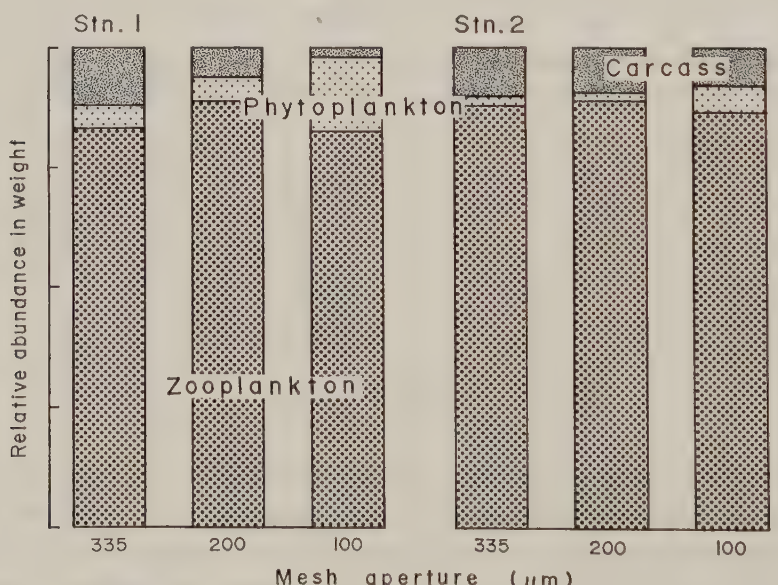


Fig. 2. Relative abundance of zooplankton, phytoplankton and carcass in corrected weight. The plankton samples were caught by triplet nets of different mesh sizes at 2 stations in the Goto-nada waters, May 1987.

zooplankton and the residue is equal to the non-sorted material frozen, the biomass of zooplankton and the concentration of the residue were calculated by proportional division from the ratio between the zooplankton and the residue. As the residue includes phytoplankton, "carcass" was obtained by subtracting phytoplankton from the residue. Phytoplankton in the gut of animal was neglected as mentioned above. Relative abundance of each item in corrected weight is summarized and illustrated in Fig. 2.

The weight of zooplankton occupied 83 to 89% of the whole collection being rather constant regardless of the mesh size and sampling site. These values are higher than those observed in March, 35 to 78%.[2] The percentages of phytoplankton biomass ranged from 2 to 16%, and were larger in the smaller meshes, being similar to those obtained in March.[2] Phytoplankton biomass retained by plankton net was 0.1 to 0.8% of that of the ambient water (Tables 1, 2). The carcass occupied 2 to 12% of the whole, showing relatively larger percentages in larger meshes. The relative abundance of phytoplankton and carcass must vary according to the evaluation of the amount of phytoplankton, namely carbon/chlorophyll*a* ratio. As a matter of fact, the amount of phytoplankton exceeded that of "carcass" for 3 cases which were finally eliminated from the calculation; 1 for 335 μm mesh net and 2 for 100 μm at Stn. 1 (Table 2). The carbon/chlorophyll ratio is indeed variable (previous data complied by MORIOKA et al.[2]), and to adopt this assumption may not be always practical in such an investigation. The shorter distance of vertical haul at Stn. 2 might have given the larger component ratio of phytoplankton in the net collection. Indeed the relative thickness of phytoplankton rich layer varies according to the distance of haul through vertical column including phytoplankton poor layer. The present results, however, did not show such an evidence. To know the precise amount of zooplankton in the plankton net collection, observations in the representative seasons in a precise area should be necessary. The hand sorting should be used, though it requires labor and time a more until practical method is explored and developed.

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REEFRENCES

1) J. HIROTA and J. P. SZYPER 1976 : Standing stocks of zooplankton size–classes and trophic levels in Kaneohe Bay, Oahu, Hawaiian Islands. *Pacific Sci.*, **30**(4), 341–361.

2) Y. MORIOKA, J. NAKASHIMA and K. KIMOTO 1990 : Zooplankton biomass share of the collection with plankton net in the waters to the west of Kyushu, March 1987. *Bull. Seikai Natl. Fish. Res. Inst,.* (68), 143–152.

3) S. MOTODA 1959 : Devices of simple plankton apparatus. *Mem. Fac. Fish., Hokkaido Univ.*, **7**(1/2), 73–94, 8 pls.

4) M. OMORI 1978 : Some factors affecting on dry weight, organic weight and concentrations of carbon and nitrogen in freshly prepared and in preserved zooplankton. *Int. Revue ges. Hydrobiol.*, **63**(2), 261–269.

プランクトンネット採集物中に占める動物プランクトン生物量の評価（続報）

中嶋　純子・森岡　泰啓・木元　克則

抄　　録

動物プランクトンの採集にはプランクトンネットが最もふつうに使用されているが，ネット採集では目的である動物プランクトン以外に植物プランクトンやこれらの屍骸などをも同時に捕集される．水域の動物プランクトン生物量の迅速な評価のため一般に行われている採集物全量の湿重量や乾燥重量をそのまま用いると，夾雑物をも合わせて計ることになり，動物プランクトンの生物量が過大視される．

本研究は，1987年3月の五島灘における前報（西水研報告第68号，1990）に引き続き，同年5月同じ2地点において口径45cm，網目幅100，200，335μmの3連型プランクトンネットの鉛直曳を繰り返して行ったものについてである．採集物を等分割して目的に応じた処理後に保存し，冷凍保存標本については乾燥重量を測定し，ホルマリン固定の標本について実体顕微鏡下で動物プランクトンを手作業によって選り分けて動物と動物以外の乾燥重量を計った．分光法によるクロロフィルa量から植物プランクトン乾燥重量を算出し，これを動物以外の重量から差し引いて死骸の量とした．以上のことからプランクトンネット全採集物に占める動物，植物，死骸それぞれの量を得た．

動物プランクトン量の比率は，3月の比率と比較し，83～89％と高かったが，網目の差による変化は少なかった．植物プランクトンは，2～16％を占めて網目幅が小さくなるにつれて比率が増した．動・植物の死骸はその逆の傾向を示し，2～12％であった．

親潮水の変質過程について

森 永 健 司*・杉 本 隆 成**

On the Mixing Process of the Oyashio Water off South-East coast of Southern Part of Kuril Islands

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ABSTRACT

Focusing on the process of mixing between Okhotsk Sea Water (OSW) and East Kamchatka Current Water (EKCW), resources of the Oyashio Water (OW), we have made some experiments around the Kuril Islands in the western North Pacific from September to November 1991.

In our experiments, two drifting buoys with attached ALGOS transmitter have been deployed to observe the path of the Oyashio current. Unfortunately one of them was lost soon after release. At the same time, oceanographical survey was carried out.

It was revealed that 1) the Oyashio current had been flowing along the south coast of the southern Kuril Islands, where OSW and EKCW had begun mixing, 2) off Shikotan island, the Oyashio current path took a great offshore bend which was caused by anticyclonic circulation induced by the Kuroshio Warm Core Ring (KWCR), 3) mixing rate of OSW and EKCW increased gradually, and its time derivative had a constant value, and 4) in the periphery of the subarctic boundary, appeared a rapid stream that reached up to 60 cm/sec.

Consequently, characteristics of the OW might have varied in accordance with the change of its path influenced by the KWCR. And also high velocity periphery current of the subarctic boundary reveals the existence of rapid eastward counter-current of anticyclonic subarctic circulation at the western part of the North Pacific.

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は じ め に

親潮と黒潮が接する三陸沖は世界三大漁場の一つとしてよく知られており，我が国の水産業にとって重要な海域である．この海域における水産海洋学的研究の歴史は古く，なかでも漁場環境に関して数多くの研究が行なわれてきた．しかし，その多くは黒潮に焦点を当てた研究であった．親潮に関しては領土問題等の関係から長期間にわたり観測が制限され，新しい技術による詳細な観測が行われていなかった．そのために親潮の実態は不明瞭で，Favorite et al.[1] らが示したように〝親潮はオホーツク海を起源とし，明確には定められぬ乱流” と考えられ，黒潮と同じ意味での海流として捉らえられていなかった．

親潮の水塊特性に関して，西山[2] は水温 5 ℃以下，塩分34.0以上で，サーモステリックアノマリー（Δst; 単位は $\times 10^{-8} m^3 kg^{-1}$）100以下の寒冷水の上に分布する低塩分・豊酸素の比較的一様な低温水であると定義した．一方，大谷[3] は中層以深での水塊解析結果から，親潮の起源水はオホーツク海から流出したオホーツク海水と，東カムチャツカ海流水が千島列島間の海峡で鉛直及び水平混合によって形成された海水であると報告している．しかし流れと関連付けた親潮水の形成過程は論じられていない．

1987年～1991年にかけて水産庁北海道区水産研究所が親潮源流域を中心に広域的な海洋観測を実施した結果，親潮の流れは順圧的性質を持ち，流量が 20Sv（$1Sv = 1 \times 10^6 m^3 sec^{-1}$）以上に達することなどが明らかとなった[4,5]．この値は黒潮のそれに匹敵するものであり，Favorite et al.[1] が言うように，単に乱流と

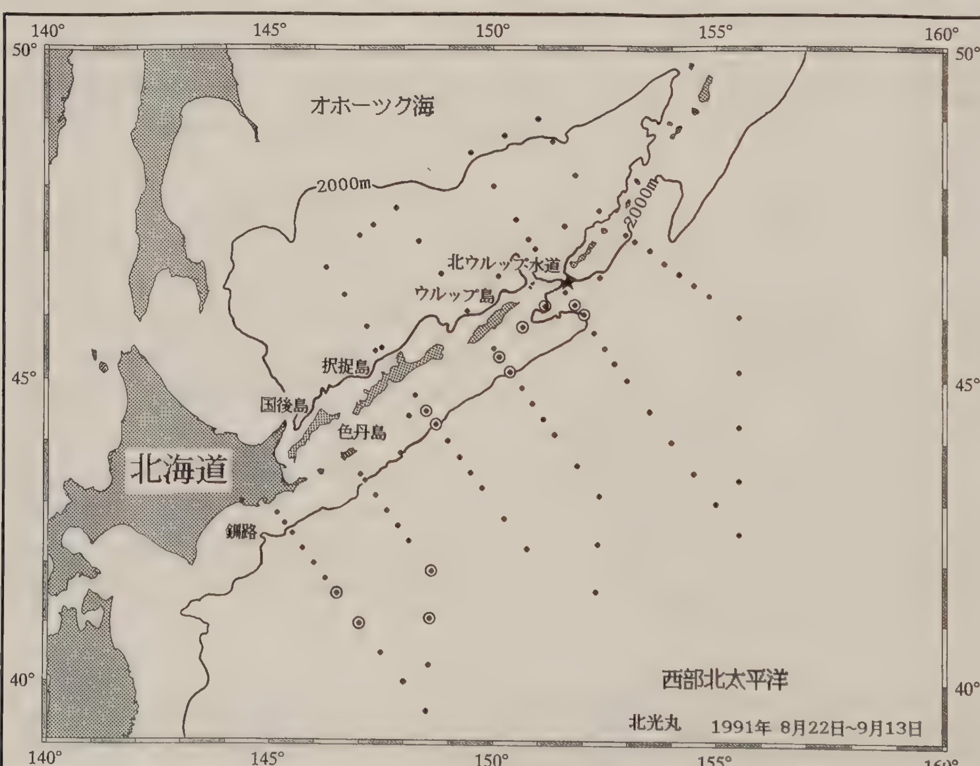


図 1.　観測海域（1991年 8 月22日～ 9 月13日）およびＣＴＤ観測点（・；ただし混合率算出のために用いた観測点は◎）並びにアルゴスブイ投入点（★：46°30′N 151°30′E）

理解するには大きい値である．また，川崎[6]は択捉島に沿い南西方向に流れる水を親潮コア水（以下親潮水とする）と定義し，地衡流近似から求めた流量をもとにその流路を示した．さらに等比容面上の塩分分布から流路に沿った親潮水の水系特性の変化を示したが，その流路は地衡流近似によりオイラー的に推定されたもので，水塊を追跡して得られたものではない．水塊の特性は時間的に変化するが，この変化過程を捉えた報告は見当たらない．

著者らは，水塊解析から得られた上述の親潮像にアルゴスブイによるラグランジュ的な流れの情報を加えて親潮水の変質過程について考察したので，ここに報告する．

方　法

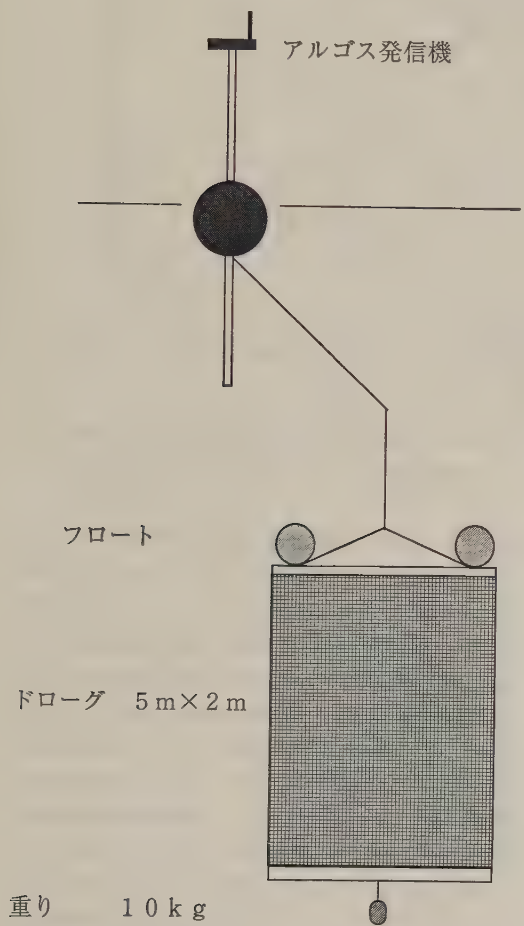


図 2．アルゴス発信機を取り付けた漂流ブイの構成図

著者らは1991年８月22日～９月13日にかけて北海道区水産研究所所属の北光丸（466トン）を用いて海洋観測を行なった．観測海域は図１に示す南部千島列島沖合及び沿岸域である．観測期間中の1991年９月１日に，北ウルップ水道内（図１中の★印）においてアルゴスブイ（20 m深にドローグを垂下）を投入した（図２）．アルゴス発信機は11月21日までの約80日間正常に作動し，長期にわたる漂流資料を得た（位置精度：半径１km）．なお，ブイを投入した北ウルップ水道は，その最大水深が2,600 mに達し，南部千島列島中で最も深い海峡である．ここはオホーツク海水が太平洋へ流出する主たる出口にあたる．

次に，オホーツク海水と東カムチャツカ海流水との混合率を，CTD観測結果から河野[5]の方法に従って求めた．この方法は季節変化が及びにくい深度で等比容面混合（isopycnal mixing）を仮定し，オホーツク海水および東カムチャツカ海流水の源流域での Δ st-T 曲線をもとに混合率を求めるものである．従って季節変化の大きい表層付近においては用いることができない．そこで，Δst＝120 の深度分布が力学的高低偏差とよく対応すること[6]，および Δst＝100 が親潮最深部に対応すること[2]から，上記両比容面上での混合率の変化をアルゴスブイの漂流軌跡に沿って求める．

結　　　　果



図 3.　表面水温分布（℃，1991年8月22日～9月13日）（W，Cはそれぞれ相対的な高温部，低温部を示す）

1)　南部千島列島周辺の海況

ここでは観測期間内（約20日間）に水系の分布が大きく変化しないと仮定し，表面水温分布（図3）から海況を概観する．最低水温4℃の水塊が北ウルップ水道付近に分布し，それを中心に冷水域が広がっている．また，その一部は南部千島列島沿いに南西に張り出している．この冷水域がオホーツク海水の分布を示している．また，国後島の南東（42°00′N，149°00′E 付近）において，13℃等温線で示される親潮水が南方に大きく張り出し，41°40′N，148°00′E 付近で湾曲し，時計回りの流れに巻き込まれる形となっている．このことは，42°30′N，148°00′E 付近を中心とする半径60マイル（約100km）程度の黒潮系暖水塊（時計回りの渦）が存在していることを示唆している．さらに，水平傾度の大きな部分が 41°00′N，148°00′E 付近から東北東方向に延びている．これは親潮域と黒潮続流域との間に形成される亜寒帯前線を示している．

次に，親潮水の平均的な流れの場を見るために，⊿st＝120 の深度分布を図4に示す．地衡流近似を仮定すると，北半球では等 ⊿st 面の深いところを右に見ながら，その等深度線に沿って流れが生じる．これによると，ウルップ島のオホーツク海側には等 ⊿st 面の深い海域があり，高気圧性渦が形成されている．この高気圧性渦は，宗谷暖流水が夏期に千島列島北側に広がり形成されたものである[7]．この高気圧性渦が夏期に拡大し，それに伴って北ウルップ水道北側に南方向の流れが生じ，太平洋側へのオホーツク海水の流出が助長されると考えられる．

南部千島列島の太平洋側では等 ⊿st 面の等深度線が列島に沿っており，流れもこれに沿う形で生じている．色丹島の南東方では深度が深くなり，等深度線が楕円形を示している．このことは楕円形の高気圧性渦が存在することを示している．この渦は表面水温分布（図3）に見られた黒潮系暖水塊に対応するものであ

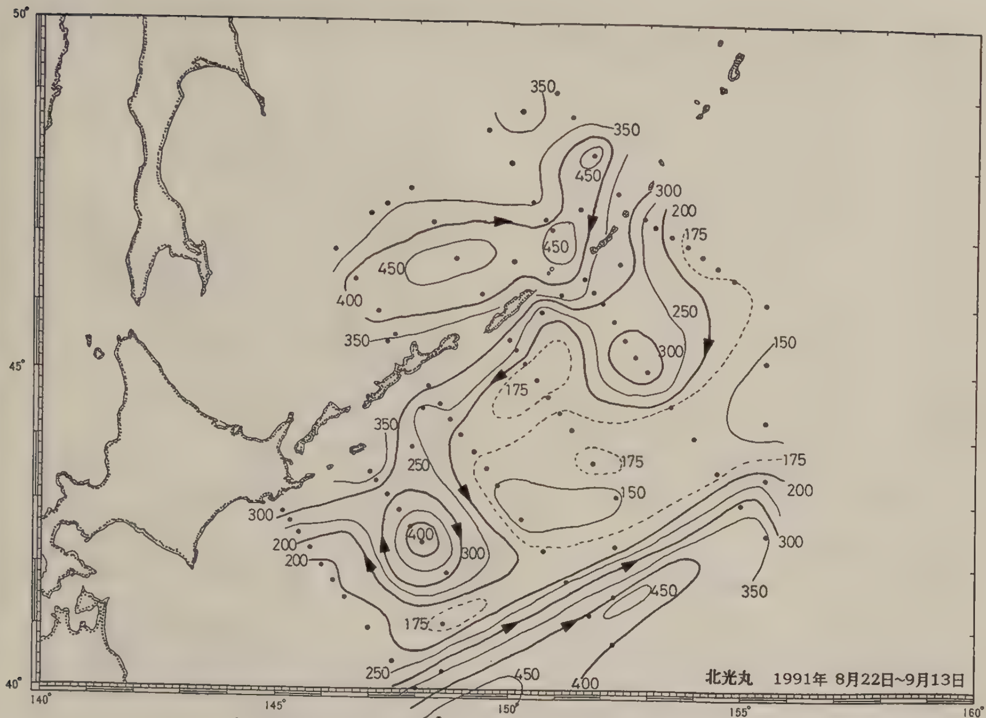


図 4．等 Δst 面（$120\times10^{-8}m^3kg^{-1}$）の深度分布（m）

る．暖水塊の高気圧性循環に伴う地衡流速を算出すると，最速部の表面流速は1.4ノット（$70cmsec^{-1}$）程度となり，流量は約 9 Sv 程度と見積もられる．

以上の結果をもとにした海洋構造の模式図を図 5 に示す．大きく分けると，オホーツク海水と東カムチャツカ海流水は択捉島南東方で合流して親潮水となり南西方向に流れる．親潮水は色丹島沖にある黒潮系暖水塊のまわりを時計回りに流れる．その南方では親潮水と黒潮続流水との間で亜寒帯前線が形成され，東方向に流れていると考えられる．

2） 漂流観測結果

ブイの漂流軌跡（図 6a）と漂流速度の時間変化（図 6b）の特徴を見る（図中のA～C点は漂流軌跡を区分するために便宜的に設けた）．

投入点～A点間では北ウルップ水道の太平洋側出口より南下したのち，半径20kmほどの小さな円を描きながら右廻りに移動した．この間の平均漂流速度は12マイル日$^{-1}$（$25cmsec^{-1}$）であった．その後，南西向きに方向を変え南部千島列島沿いに移動し，約10日間で色丹島の東方40マイル（約70km）に達した（A～B点）．この間の平均漂流速度は14～16マイル日$^{-1}$（$35cmsec^{-1}$）であり，やや速くなった．このA～B点間での漂流速度は，過去に報告されている親潮の地衡流速とほぼ一致する．

B～C点間では，色丹島の東方で移動方向が南東方向へと変化し，色丹島沖から半径100km程度の円を描くように大きく右旋回する様子が見られた．移動方向が南東へ変化するB点では，漂流速度が激減し 8 マイル日$^{-1}$（$15cmsec^{-1}$）であったが，B～C点間では16マイル日$^{-1}$（$35cmsec^{-1}$）と速くなった．これは暖水塊に伴う強い時計回りの流れに取り込まれたためであろう．地衡流近似より暖水塊の表面流速の最大値は，70 $cmsec^{-1}$ と見積もられたので，ブイは最大流速部よりも外側に取り込まれ漂流したものと考えられる．

次に，C点の付近で約 1 カ月間滞留した後，11月に入ると亜寒帯前線に伴う強い流れに取り込まれて東方に移動した．この時の平均漂流速度は1.2ノット（60 $cmsec^{-1}$）であった．この値は漂流ビンで求められた亜

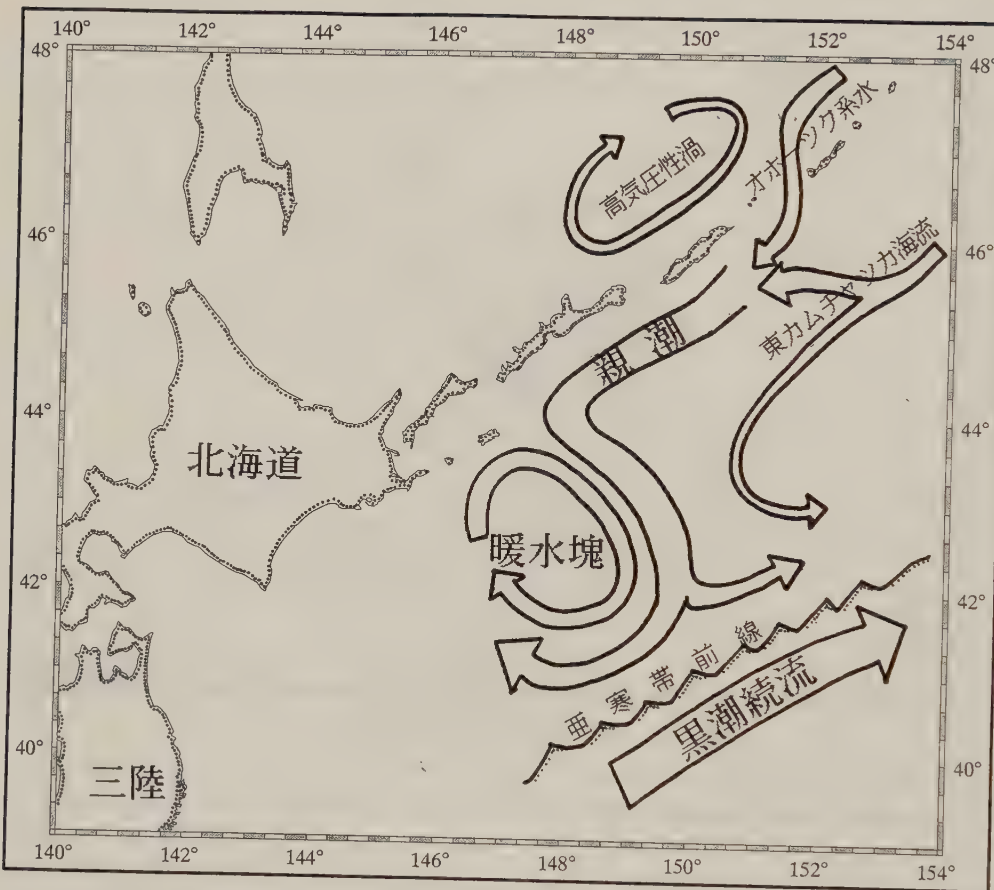


図 5. 海洋構造の模式図

寒帯前線での表面流速（5～10cmsec^{-1}）をはるかに上回っている[8,9]．本観測結果より得られた大きな漂流速度は，亜寒帯循環の南西部に大きな流量を持った東方向の流れが存在することを裏付けている．

考　　察

1）漂流軌跡と海洋構造

北ウルップ水道の太平洋側出口に投入したアルゴスブイは，南下して右廻りの漂流軌跡を示した．これは，前述のオホーツク海側にある高気圧性渦が拡大し，その一部が太平洋側まで張り出したことによるものである．

その後，ブイはウルップ・択捉・国後島の太平洋側および黒潮系暖水塊のまわりを等 Δst（＝120）面の等深度線に沿って直線的および円弧状に移動したが，小さな蛇行や細かい擾乱を示す顕著な形状の変化は見られない．これは南部千島列島沿いおよび黒潮系暖水塊周辺の流れが安定していることを示唆しており，流れの鉛直シアーと密度成層に伴う傾圧不安定擾乱が生じていなかったことを示している．また等比容面に対して鉛直方向の混合（diapycnal mixing）が小さいことも示す．

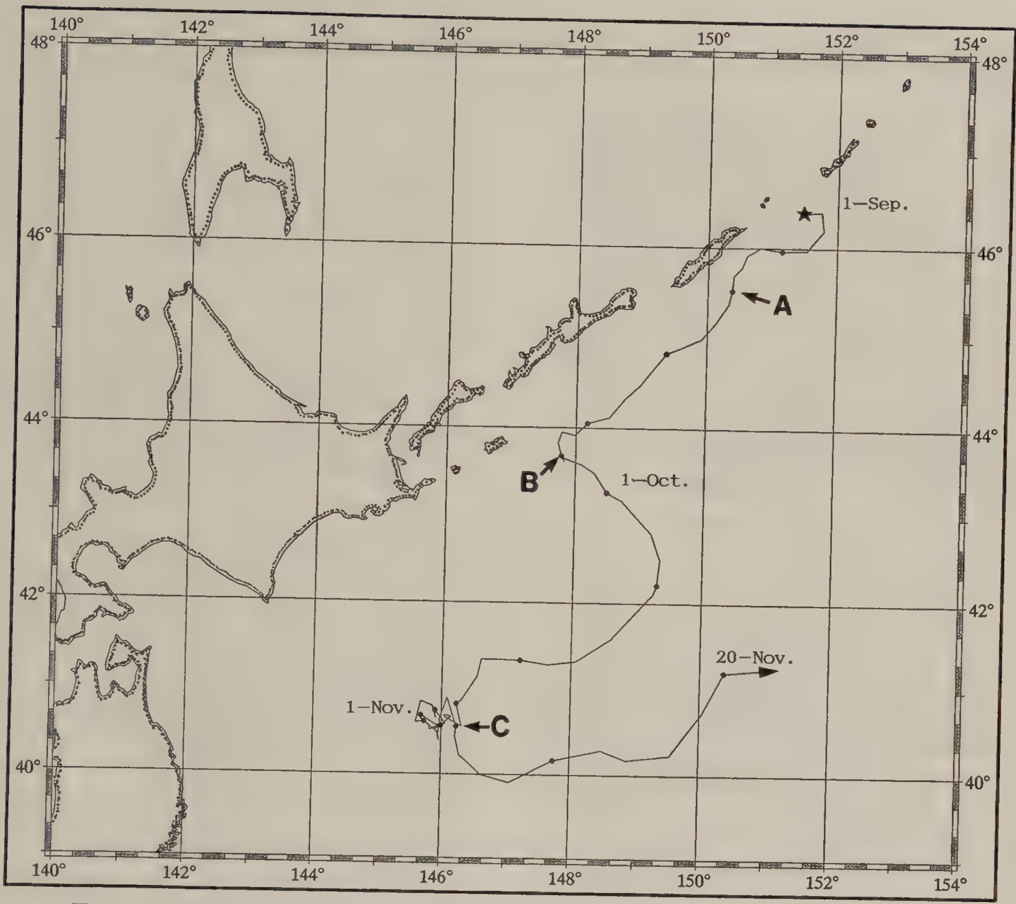


図 6 a.　アルゴスブイの漂流軌跡（1991年9月1日～11月21日，投入点は★印，黒丸は5日毎の位置）
（図中A～C点は漂流軌跡を区分するために便宜的に設けた）

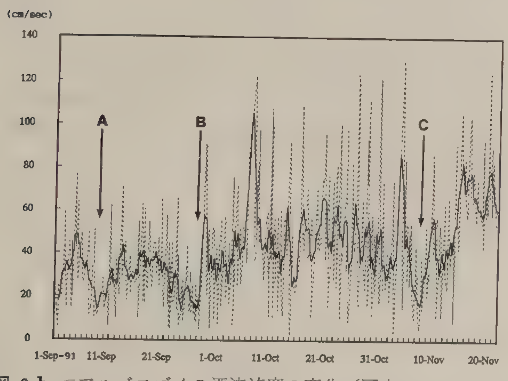


図 6 b.　アルゴスブイの漂流速度の変化（図中のA～Cは図6aと対応：実線は10日間の移動平均値）

その後，約1カ月間程滞留した後，11月になりブイは南方へと移動し，亜寒帯前線の強い流れに取り込まれ，平均60cmsec^{-1}，最大75cmsec^{-1}の速い速度で東方へと流れた．このころ大陸の高気圧が発達し，東京では11月9日に木枯し1号が観測されている．このことから，C点で滞留していたブイが南方へ移動したのは，北西からの強い季節風の吹出しによるものと考えられる．

2）オホーツク海水と東カムチャツカ海流水との混合過程

上記のような経路をたどると考えられるオホーツク海水は，太平洋に流出した後に東カムチャツカ海流水と混合し親潮水を形成すると考えられている[3]．河野[5]

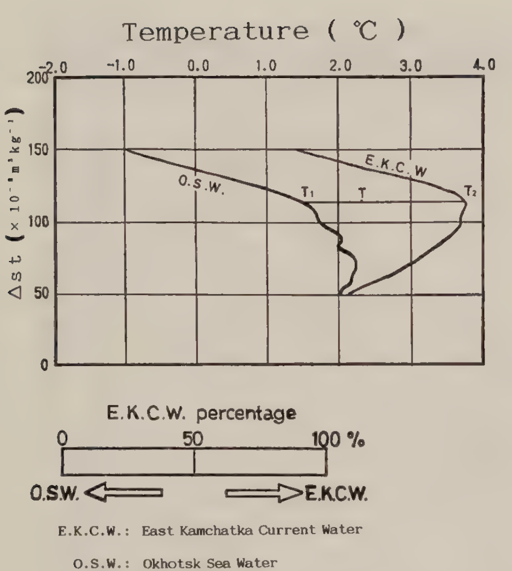


図 7. オホーツク海水と東カムチャッカ海流水の $\varDelta$st–T ダイヤグラム（河野，1990を改変）

は図7 をもとにして各観測断面における混合率をCTD 観測結果から算出し，観測断面間での混合率の分布から親潮水の混合過程について論じた．図7の $\varDelta$st−T ダイヤグラムは，既往の観測資料をもとにしてオホーツク海水の最低値と東カムチャツカ海流水の最高値をプロットして作成されたものである．

河野[5] の方法を用いて，アルゴスブイの漂流軌跡を挟む CTD 観測点（図1）での $\varDelta$st=120，100における混合率（mixing rate：以下 M. R.）の分布を図8に示す．これによるとウルップ水道出口から暖水塊

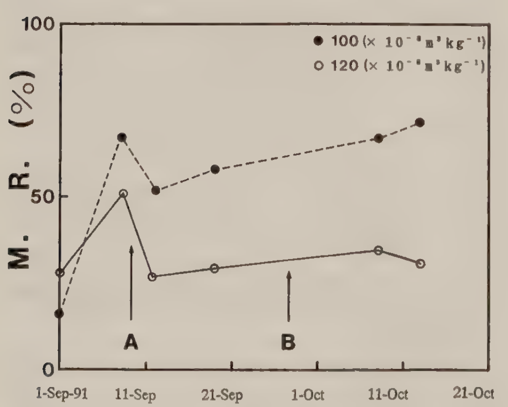


図 8. アルゴスブイの軌跡に沿った点での混合率（M. R.）の変化（図中のAおよびBは図6aと対応）

南東部までの区間の混合率は，アルゴスブイ投入点〜A点を除いて，両 $\varDelta$st 面上ともほぼ一定の勾配で変化している．このことは混合率の時間変化がA点〜C点間において一定であったことを示している．すなわち，オホーツク海水と東カムチャツカ海流水の混合は，間欠的ではなく連続的に進むことを示唆している．また，両 $\varDelta$st 面の混合率の違いは，オホーツク海水の鉛直分布が太平洋の沖側に向かって浅くなり，より深い $\varDelta$st=100 では，東カムチャツカ海流水がより多く含まれているためと考えられる．

次に図8の混合率の変化の勾配を比較すると，$\varDelta$st=100 の方が若干大きい．これは，$\varDelta$st=100 面上での流速が小さい（択捉島沖での $\varDelta$st=120，100面上のそれぞれの地衡流速は9.1および7.3cm sec^{-1}）ことにより両水系の接触時間が多くなり混合がより進むために起こるものと考えられる．そこで混合率の時間変化を δ，アルゴスブイの平均漂流速度を υ，各 $\varDelta$st 面上での流速を υ^* とすると，各 $\varDelta$st 面上での混合率の変化（δ^*）は以下の式より求まる．

$$\delta^* = \upsilon' / \upsilon * \delta$$

ここで υ' として上記の地衡流速値を用いる．（地衡流速値はA〜B点間で得られた値）

すると

$$\delta^{*120} = 0.74 \times 10^{-1} \text{（日}^{-1}\text{）}$$

$$\delta^{*100} = 1.21 \times 10^{-1} \text{（日}^{-1}\text{）}$$

となり同程度の値を示す．つまり，両水塊の接触時間が長ければ混合は進み混合率が大きくなる．上記の値から，完全に混合（M. R.=50）するためには400〜700日を要するため，両水系が完全に混合せずに道東海域に到達することを示唆している．すなわち親潮水が形成される過程において，黒潮系暖水塊などにより親潮水の流路が変動すると，ウルップ水道から北海道・三陸沖に到達するまでの距離が変化するために水塊特性が大きく変化すると考えられる．

お わ り に

本報は，1991年9月1日に北ウルップ水道に投入したアルゴスブイの漂流軌跡と，同時に行った海洋観測結果から，親潮水の混合過程を黒潮系暖水塊による流路変動と関連付けて考察したものである．まとめると以下のとおりである．

1) ブイの漂流軌跡は千島列島の岸近くを通り色丹島沖から南東方向へと変化した．このことは，この海域で親潮の流路が大きく変化したことを示している．その原因は，釧路沖にある黒潮系暖水塊の時計周りの循環によることが海洋観測結果から明らかになった．

2) 親潮水の混合率の変化は一定であるため，黒潮系暖水塊を迂回する場合は混合が進み，水塊特性が大きく変化する．このことは，三陸地方の気候変動や生物の生息環境に対しても大きな影響を与えると考えられる．

3) ブイの漂流速度は亜寒帯前線付近において最高60cmsec^{-1}に達する．この値は同じ海域における漂流ビンの流速（5～10cmsec^{-1}）を大きく上回っている．この大きな漂流速度は，亜寒帯循環の西側における大きな流量を持つ東向きの流れの存在を裏付けるうえで重要な資料になる．

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文 献

1) F. Favorite, A. J. Dodimead and K. Nasu 1976: Oceanography of the Subarctic Pacific Region, 1960–71, International North Pacific Fisheries Commission (33): Vancouver.

2) 西山勝暢 1984：概説：親潮．海洋科学，**16**(12)，672–682.

3) 大谷清隆 1989：親潮水形成に関わるオホーツク海の役割．海と空，(65)，63–83.

4) 柏井 誠・河野時廣 1989：親潮の流れと水系．日本海洋学会春期大会講演要旨集，82–83.

5) 河野時廣 1990：親潮の水系輸送について．月刊海洋，**22**(4)，187–198.

6) 川崎康寛・河野時廣・柏井 誠・奥田邦明 1991：Ⅰ．1989年夏季の傾圧流量収支と親潮水系の流路．北水研研報，(55)，79–89.

7) M. Wakatsuchi, and S. Martin 1991: Water circulation in the Kuril Basin of the Okhotsk Sea and its relation to eddy Formation. *J. Oceanogr. Soc. Japan*, **47**(4), 152–168.

8) T. Hirano, 1958: The Oceanographic study on the subarctic region of the Northwestern Pacific Ocean–Ⅲ. On general condition of the sea in spring and summer. *Tokai Reg. Fish. Lab.*, (20), 23–46.

9) 秦 克己 1963：北太平洋における海流瓶の投入結果について．日本海洋学会誌，**19**(1)，6–15.

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